REPORT ON

THE

A T O M

REPORT ON THE ATOM

What You Should Know
About the Atomic Energy Program
of the United States

BY

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PREFACE

The Why of This Book

I CANNOT RECALL just when the idea of writing a book on atomic energy first occurred to me. I think it developed in nebulous form in the first few weeks after my appointment to the Atomic Energy Commission in 1949, when I was trying to educate myself about the American atomic energy program as fast as possible. I soon discovered that this was not easy. While there was much information available, most of it was either too technical or altogether too popular to be of much real value to the average adult citizen. At one end of the scale were literally tons of books and papers prepared for the chemist, the physicist, and the engineer. At the other were a good many volumes and pamphlets, even comic books, designed to explain the atom and the fission process to the layman. Unfortunately, outside of the government's official reports, there was very little in between these two extremes, very little, that is, that attempted to describe the atomic energy program itself or to convey a real feeling for the many great problems which face the nation in the atomic energy field—problems with which I, as a Commissioner, would have to deal. It was about at this point, I think, that I knew I must try my hand at a book which would help fill this void.

This is not a technical book If it were, I would be the last to attempt to write it Neither is it a book of personal reminiscences, although it might be more entertaining, albeit less instructive, if it were Neither is this a posterity letter designed to demonstrate how perfect the atomic energy program was during the days when I had a considerable measure of responsibility for it Any person in public service who has the rather undramatic job of keeping his nose to the grindstone of administrative duty finds it very hard to appreciate a contemporary who has the time or the inclination to engage in the bureaucratic pastime of "building a record"

Unfortunately, this is also not a book dealing with the people of the atomic energy program who deserve the medals—the people who make the program tick, the devoted backstage heroes on the staffs of the Atomic Energy Commission and its field offices and in the industrial concerns that carry so much of the load

This book, instead, is an attempt to describe in straightforward and simple terms the major segments of the atomic energy program of the United States, which must be understood by government officials, leaders in industry, and persons in all walks of life if we are to survive and handle ourselves wisely in the atomic age

About all most people know of the atomic energy program today is that it is big, costly, and complicated, and that it is devoted primarily to bomb-making and may eventually be devoted to more peaceful objectives I fully appreciate that there are people who do not want to understand any more than this Some have assumed that secrecy forecloses such understanding Others assume that atomic energy is so technically complicated that the effort spent in trying to understand it would bear little result There are still others who, consciously or subconsciously, look upon the atom as something so sinful or frightening that they try to put it out of their minds None of these reasons

supplies a legitimate rationale for continued ignorance in a world where continued ignorance may well be the most sinful and frightening thing of all.

What appears in the following pages is a report on the atom as I know it. That particular atom is made up of many more parts than electrons, protons, and neutrons. Buzzing around, and very close to the nucleus of the atom I know are budgets, appropriations, Congressional hearings, labor disputes, materials shortages, prima donnas, earnest and patriotic people, irresponsible people, and all grades in between: spies, martyrs, civilians, soldiers, heroes, and heretics. It would take many volumes to tell the whole story, but I believe that in this one volume I have touched on the major segments. I hope I have always been factual, except in those portions where I have indicated a drift to opinion. Above all, I hope that this work will shed a little light—if ever so small—on a very dark area, and perhaps also encourage the lighting of other lamps for the unknown paths ahead.

I am indebted to many people for the knowledge I have gained and attempted to report here. I am particularly indebted to Mr. Oliver Townsend, my personal assistant for the past two years, for his frank and unfailing criticism, the highly perceptive quality of his mind, and the sharpness of his editorial pen.

GORDON DEAN
Las Vegas, Nevada

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CHAPTER 1

The American Approach to the Atom

LIKE almost everyone else, I first heard of the American atomic energy program on August 6, 1945, when President Truman announced to the people of the United States and of the world

"Sixteen hours ago an American airplane dropped one bomb on Hiroshima, an important Japanese Army base That bomb had more power than 20,000 tons of TNT It is an atomic bomb The force from which the sun draws its power has been loosed against those who brought war to the Far East"

When this historic announcement was flashed across the news wires of the world, I was in London I was there as an assistant to Justice Robert H Jackson, who had been designated to serve as chief prosecutor of the major Nazi war criminals at the forthcoming Nuremberg trials We were in London to develop with our Allies, the British, the French, and the Russians, a charter setting forth the principles and procedures under which the perpetrators of World War II were to be brought to the bar of justice The charter had just been agreed upon after eight long weeks of negotiation, and we regarded the date of its signing, August 5, as a significant one, for it branded as criminals not only those who had launched World War II, but also those who would launch all future wars

Those midsummer days of 1945, when the war against Germany had been won and the final assault against Japan was being mobilized, were fateful ones on many counts, and they held many significant dates. In the two weeks leading up to August 6 and Hiroshima the world had seen the conclusion of the Potsdam Conference, the issuance of the Allied ultimatum against Japan, the approval of the United Nations Charter by the United States Senate, and the signing of the agreement establishing the principles under which the Nuremberg defendants were to be tried. Those were days of destiny and decision, when men wrestled heroically with the fundamental questions of peace and morality while they mobilized their strength and resources for the final push against those who had defied and violated every decent human instinct.

It was into this setting that the atomic bomb burst. Its brilliant light illuminated in stark outline the hopes and fears of mankind for the future, and its towering radioactive cloud hung like a huge question mark over the efforts of those who were striving to establish a permanent code of international morality and a system under which a lasting peace could be built. I well remember the profound impression the news from Hiroshima made upon those of us who were in London.

After the President's initial announcement, news of the atomic bomb and the program that had produced it poured in from Washington, from Hiroshima, from Oak Ridge, from Hanford, from Los Alamos, and then, on August 9, from Nagasaki, the second target city. On August 10, four days after the first atomic bomb had been used in war and 1,342 days after Pearl Harbor, the Japanese formally offered to surrender, and mankind was left to speculate upon the advantages and hazards of existing on a planet that also contained the powerful but unruly atomic genie released at Hiroshima.

During the period immediately following Hiroshima and

Nagasaki, there appeared in the press of the world many moving expressions of fact and fallacy about atomic energy that persist even today With the information that became available, there also began to be circulated the misinformation that has ever since plagued those who would try to educate the peoples of the world about the atom and its implications

In the press of the day, for example, one may find reports of how both the Hiroshima and Nagasaki bombs were dropped by parachute Actually, neither was One may find also a report on how the Hiroshima bomb caused more damage "because it was exploded in the air" Actually, both bombs were air bursts There were also learned treatises on how the cities of Hiroshima and Nagasaki would be unfit for human habitation for many years to come because of the radioactivity left behind by the atomic explosions As we now know, both cities were reoccupied almost immediately without ill effect to those returning One of the more tragic fallacies was the widely circulated belief that the Japanese were "after the bomb too" because the American occupation forces found a cyclotron in a Japanese university laboratory In an excess of poorly informed zeal the occupation troops destroyed this valuable research instrument under the impression that it was useful in the development and manufacture of bombs It of course was not useful for this purpose, but the Japanese scientists nevertheless had to wait seven years before they were in a position to obtain a replacement from an American manufacturer The Atomic Energy Commission was glad to approve the export of this replacement last year

Among the facts reported in the British papers of the time were many having to do with the valuable contribution made by British scientists to the American bomb program, first as pioneering research workers in their own laboratories and later as members of the British scientific

mission to the United States The contributions of people like Sir James Chadwick and Professor Rudolf Peierls were described, and mention was made of the work of the German refugee Otto Frisch, as well as of the French scientists Hans von Halban and Leo Kowarski, who escaped to England after the fall of France with forty gallons of heavy water, then practically the entire world stock of this valuable material Among those to whom a good deal of credit was given for developing the data upon which the calculations of the so-called "critical size' of the bomb were based was one Klaus Fuchs of Birmingham University and the British mission to Los Alamos, who now languishes in a British jail after achieving world-wide notoriety as the "master traitor" of World War II

The newspapers of the day recorded also all the fears and frustrations and hopes that still motivate the peoples of the earth in their dealings with atomic energy In fact, as one looks back, it is surprising how little has been added in the ensuing years in the way of new ideas concerning the implications of this new force As I was in London at the time, most of the initial reactions to the news of the bomb that I heard and read were those of Britons But they were not just British reactions, they were human reactions, and they were the same all over the world Thus, in London, in the days immediately following Hiroshima, we were able to read such comments as the following

'It is indeed on the creative side that this new source of energy presents the most hopeful and fascinating possibilities," said a British government official in the *London Chronicle* "It may not be rash to predict that, sooner or later, [atomic energy] will establish itself economically as well as scientifically and command the field' This same official went on to express the prophetic opinion that "for the moment, the United States, in terms of power politics, can dominate the world In comparison Russia is only a

vulnerable secondary power That situation cannot, in the nature of things, last"

In the *London Sunday Graphic* an American physicist of the Carnegie Institution of Washington wrote "The English coal mines are safe in the immediate years ahead Yet within the century it is probable that the mining of coal to produce power may have no greater place in the world's economic system than does the burning of wood today"

The *London Observer* early noted the question of the morality of the bomb which was already beginning to weigh heavily on the conscience of the Western World In defense of the action taken by the United States, it editorialized "Had myriads of Superfortresses and Liberators area-bombed Japan into surrender by old-style methods, doing the same destruction as two A-bombs with considerable loss of American and British life, would morality have been the more observed?"

The dominant question of war and peace in the new age obviously was very much in the minds of everyone Robert Boothby, a member of the British parliament, wrote in *News of the World* "The atomic bomb means the end of war or the end of the human race Sooner, rather than later, the bomb must be confided to a world authority with effective power, charged with the specific duty of establishing the reign of international law" To this the London newspaper *The People* added 'What was intended in the first instance to bring Japan to her knees has become an ultimatum to all the peoples of the earth It warns them that they must keep the peace or perish' And the *Observer* said "Let us thank Providence for the near end [of the war] and pay our duty to the future, which is to think and think hard" All of these expressions were uttered within five days after the first bomb was dropped

Meanwhile, in the United States many of the same thoughts and the same questions were being expressed in

almost the same words Thus one may read in the *St Louis Post-Dispatch* of August 7, 1945, the following comment by Dr H A Wilson of Rice Institute "Some international authority should take control of the world's uranium supply to see that mastery of the destructive principle of atomic disintegration does not fall into the wrong hands"

In the same issue the *Post-Dispatch* editorialized "Imagination leaps forward to visualize the use of atomic power for man's comfort and enjoyment in generations to come To be sure, many men will have to give much more devoted labor before we can put it to work Either the world's people—our own included—will learn to use it not for war but for peace, or else science has signed the mammalian world's death warrant and deeded an earth in ruins to the ants"

The *New York Times* speculated that "in countless fields of industry and transportation the events set in motion by the first trial of the new bomb at Alamagordo Airfield, New Mexico, and the first combat use at Hiroshima may be the first links in a chain of development profoundly affecting civilization" But it warned "With the horrible prospect of utter annihilation opened by the atomic bomb, it is hard to imagine how the people of any nation on earth can possibly want another war We must begin systematically to reduce and eliminate if possible all the chief causes of war'

It was also in the *Times* that Brigadier General David Sarnoff interjected the realistic and very practical notion that, until a world organization to achieve and maintain a lasting peace has proved its effectiveness, "we dare not relax in our efforts to provide the maximum degree of national defense attainable'

But of all the discussions going on in all parts of the world, perhaps the most hopeful notes were being struck by the clergy Thus it was that the American Bishop William T Manning said in the *New York Herald Tribune*

"This discovery gives men a frightful power for evil, but also an unprecedented power for good If the faith and conscience of mankind are correspondingly awakened by this mighty event, a new day of hope will open for the world"

At about the same time in England the Reverend W H Elliott was eloquently writing in the *London Sunday Graphic* "No pacts can save us for long, no balancing of power, no international system of safeguards It all comes down to the rock bottom of human character Are we fit to be trusted with a weapon like this? Can we make ourselves fit to be trusted?" Tentatively, somewhat wishfully, and almost pathetically, he suggested an answer "Possibly," he said, "this is just the shocking stimulus that the world has needed in all that concerns the true life of man—the piercing truth that will stab our spirits broad awake'"

Thus it was that man crossed the threshold into the atomic age pridefully yet humbly, hopefully yet fearfully, confidently yet questioningly The emotions were mixed, the reactions were varied, and the dominant fact of the times was the persistent presence of a myriad questions to which there were no ready answers The war was over, its awesome offspring lingered on It was apparent that the armies could be demobilized, it was equally apparent that the bomb could not But it had to be dealt with somehow Amid all the questions, therefore, one stood out above all others It was articulated perhaps most succinctly by the *London Observer*, which asked with simple eloquence "Where, indeed, do we go from here?'

Although this question confronted the whole world, it primarily confronted one nation the United States of America After all, it had been the United States that had developed the bomb, it had been the United States that had employed the bomb, and it was the United States that possessed the bomb exclusively "What,' the world wanted

to know, "does the United States plan to do with the bomb?" What was the American approach to the atom to be?

This was not the first time this question had been asked It had been asked many times within the American government as research progress gave increasing indication that the enormous quantities of energy contained in atomic nuclei could be released by man In fact, although the world did not know it, Secretary of War Stimson, under whose department the wartime bomb project had been carried on, had as early as May 1945 appointed a committee of distinguished government and scientific leaders to look into and formulate some basic policy positions concerning the atomic future of the United States and of the world This committee, established at the request of President Truman, included such leading figures as Henry Stimson, James F Byrnes, Vannevar Bush, Karl T Compton, and James B Conant, among others, and it had the valuable assistance of a panel of consultants composed of the atomic scientists J Robert Oppenheimer, Ernest O Lawrence, Arthur H Compton, and Enrico Fermi

Partly because of the work of this committee, and partly because of a more or less spontaneous crystallization of the views of leaders in both science and government, a tentative but nevertheless realistic United States position began to develop in relation to the atom even in advance of its unveiling to the rest of the world First to emerge were some basic premises upon which future policy could be built In general, these premises were somewhat as follows

1 That, no matter how zealously the secrets of atomic energy were to be guarded, the American monopoly was destined to end sooner or later

2 That somewhere in the field of atomic energy there was the promise of future peaceful applications which, if

properly pursued, could bring great benefit to the people of the United States and of the world

3 That the enormous potentiality of the atom for evil as well as good meant that a rather special means had to be developed to control it in such a way that the good could be released and the evil suppressed

4 That special means of controlling the atom internationally as well as nationally should be developed as matters of great urgency

5 That, until an effective system of international control could be set up and placed in effect, the United States should continue to hold on to its monopoly in the atomic weapons field

At no time, so far as I have been able to learn, did anyone in a position of responsibility suggest that "now that we have the bomb exclusively, let us go out and conquer the world" The United States has never thought in such terms, and it did not think in such terms at the conclusion of World War II

Because of the preliminary thinking that had been given to the question of atomic energy, both formally within the Secretary of War's committee and informally in the halls of government and science, President Truman was able to say in his original announcement about Hiroshima 'I shall recommend that the Congress of the United States consider promptly the establishment of an appropriate commission to control the production and use of atomic power within the United States I shall give further consideration and make further recommendations to the Congress as to how atomic power can become a powerful and forceful influence towards the maintenance of world peace" Three days later, in an address to the nation, he added "The atomic bomb is too dangerous to be loose in a lawless world That is why [we] do not intend to reveal the secret until means have been found to control the bomb

so as to protect ourselves and the rest of the world from the danger of total destruction "

Thus it was that the United States began to answer the question of what its approach to the atom was to be In its broad outline, this approach had three main objectives (1) to develop and establish an effective system for controlling the atom within the United States, (2) to help develop and establish an effective system for controlling the atom throughout the world, and (3) to hold on to the American monopoly in atomic energy until an international control system had been established, meanwhile using the atom, not for aggression or national aggrandizement, but for the preservation of world peace and the betterment of mankind

The world, for a time, breathed easier as it watched to see what these noble motives would produce

The practical problem facing the United States was that of making the wartime bomb program over into a peacetime atomic energy program designed to accommodate the enormous power of the atom for good or evil The wartime program under the direction of the never-tiring General Groves had been highly successful in achieving the goal for which it had been set up, namely, to develop and put into production an atomic bomb The United States owes the General a great debt He succeeded in an almost impossible mission But the wartime program was hardly suitable as a framework for handling the atom in time of peace In the first place, it had been started and carried on under the temporary emergency powers of the President which were due to expire after the war had been brought to its formal conclusion In addition, it was quite obvious that the wartime program was not broadly enough conceived nor deeply enough embedded in the political fabric of the nation to make it an effective instrument for controlling the unleashed atom and realizing its peaceful promise Something else was needed, but it was clear that

this "something else" would have to draw upon the experience gained with the atom in World War II

A good deal of the information concerning the wartime program became a matter of public record very quickly once the news from Hiroshima had revealed its existence In the official statements from the White House and the Pentagon, in the feature articles and news dispatches from the newly revealed laboratories and plants, and then, later, in the famous *Smyth Report*, the story began to emerge It was a dramatic story of prodigious effort, brilliant achievement, devotion to duty, and wholehearted co-operation among many varied groups in government, industry, and science It was all of these, but perhaps most of all it was the story of a magnificent gamble that paid off The highlights of this fascinating story, as I see them, are as follows

January 1939 It was in this month, when the war clouds were gathering over Europe but before actual hostilities had begun, that word arrived in the United States that two German scientists had split the uranium atom This exciting news circulated quickly through the American scientific community and the German experiment was repeated within a matter of days in a number of American laboratories, as it was in several other laboratories in other parts of the world Speculative articles began to appear in the press about the enormous amounts of energy that could theoretically be released by a nuclear chain reaction

August 1939 A group of European refugee scientists, by now living in the United States, early recognized the military possibilities of atomic energy and, fearing German efforts in this direction, organized an attempt to interest the American government in undertaking an atomic research program After an initial approach to the Navy Department in March 1939, which they did not regard as being very productive, they determined to reach President Roosevelt direct This was accomplished through the de-

vice of a letter of August 2, 1939, signed by Albert Einstein and delivered to the President during a personal conference by the Russian-born New York financier Alexander Sachs As a result of this approach, the President, at about the same time as World War II began with the German invasion of Poland, appointed a three-man "Uranium Committee" to look into the question of developing an atomic bomb This committee, on which the Army, the Navy, and the Bureau of Standards were represented, submitted a report to the President in November which described the bomb as "a possibility"

April 1940 By this month the scientists of the free world succeeded in establishing an effective system of voluntary censorship in the field of atomic energy, but not before several earlier attempts to do so had been blocked by Frédéric Joliot of Paris * Thus the atom, in the month that Norway was invaded, vanished behind a barrier of secrecy from which it has never wholly emerged

June 1940 It was in this month—the month in which France surrendered to the German blitz—that the United States began a small, integrated atomic research program under the National Defense Research Committee, headed by Dr Vannevar Bush From this point until Pearl Harbor the United States spent approximately $300,000 on atomic energy

December 1941 As a result of optimistic reports from research workers in both the United States and Great Britain, the decision was made about the time of the Pearl Harbor attack to undertake an all-out research and *development effort in the atomic energy field with the* objective of moving into full-scale production as soon as possible The entire program was placed under the newly established Office of Scientific Research and Develop-

* Apparently, according to the *Smyth Report*, "because of one letter sent in to the *Physical Review* before all Americans had been brought into the agreement.

ment, of which Dr Bush was placed in charge, with the understanding that later, if and when the construction phase was reached, the whole program would be turned over to the Army The decisions taken in December meant that the government was embarking on a program for which between four and five million dollars would have to be committed

June 1942 It was in this month—the month of the Battle of Midway—that President Roosevelt, upon the recommendation of Dr Bush and with the approval of a policy group composed of Vice President Wallace, Secretary Stimson, General Marshall, and Dr Conant, made the decision to proceed with the enormous wartime construction program that was ultimately to cost nearly two billion dollars This was the month when the bets of the 'magnificent gamble" were placed

August 1942 On August 13 the Army established a new district in its Corps of Engineers It was named the Manhattan Engineer District, and it was given the job of making the magnificent gamble pay off The following month Lieutenant (then Brigadier) General Leslie R Groves was placed in charge of the new district, and an overseeing Military Policy Committee with Dr Bush as chairman was set up in the War Department Immediately the job of selecting sites, contractors, and designs for the projected new plants began under General Groves's very capable direction

December 1942 Most historians seem to agree that it was actually on December 2, 1942, that the so-called "atomic age" was ushered in This event took place in secret in a makeshift laboratory in a converted squash court beneath the west stands of the University of Chicago's Stagg Field, where the Italian-born physicist Enrico Fermi and a small staff were working under contract to the Office of Scientific Research and Development on the problem of demonstrating that a self-

sustaining nuclear chain reaction could actually be made to work On the morning of December 2 they did it, and the first atomic pile in the history of the world was operated successfully Eagerly the code message was relayed to other scientists "The Italian navigator has landed, the natives are friendly"

May 1943 By this date, all of the research and development work being done in the field of atomic energy had been transferred from the OSRD to the Manhattan Engineer District, which since the previous September had already been in charge of all construction work From this point forward, therefore, the Manhattan District was in complete charge of the program

After Hiroshima the Manhattan District's record of achievement became known It became known, for example, how in a two-and-a-half-year period a secret city, named Oak Ridge, had been hewn out of the East Tennessee wilderness, and how two mammoth bomb-material plants and a large new laboratory, costing in all nearly a billion dollars, had been erected in the 59,000-acre reservation surrounding the town It also became known how another great plant, costing $350,000,000, had been erected on a 400,000-acre reservation in an isolated part of the Columbia River Valley in the State of Washington, and how another government town, named Richland, had grown up beside it

It became known how, in the performance of its construction and engineering miracle, the Manhattan District had relied upon the genius of American industry, and how, among many hundreds of others, the following made outstanding contributions the E I duPont de Nemours & Company, the M W Kellogg Company, the J A Jones Construction Company, the Union Carbide and Carbon Corporation, the Stone and Webster Engineering Corporation, the Tennessee Eastman Company, the Allis-Chalmers Manufacturing Company, the Chrysler Cor-

poration, the General Electric Company, and the Westinghouse Electric Corporation It also became known how the universities of the country had provided unstinting and invaluable support in scientific matters, with particularly noteworthy contributions having been made by Columbia University, the University of Chicago, the University of California, and Iowa State College

It became known how the United States had had the valuable assistance of Great Britain and Canada in the bomb development program, how Britain had sent a team of scientists to America for direct participation, and how Canada had a heavy-water plant and a government research laboratory that were co-operating directly with the American program It became known how the three Allied nations jointly operated a program for the procurement of uranium, and how a Combined Policy Committee, upon which Secretary Stimson, Dr Bush, and Dr Conant were the American representatives, had been established in August 1943 to provide over-all policy direction to the co-operative effort of the three nations

It also became known how a highly secret laboratory had been established on a mesa top at Los Alamos, New Mexico, and how the brilliant physicist J Robert Oppenheimer from the University of California had been placed in charge with the assignment of designing a workable atomic bomb It became known how Dr Oppenheimer assembled a staff of first-rate physicists from the United States and Great Britain around him, how, one day in July 1945, they took the device they had been working on down to the desert near Alamogordo, and how, at dawn of the morning of July 16, they set it off It also became known how this device performed according to the most optimistic expectations, and how, twenty-one days later, the second one worked just as successfully over Hiroshima in Japan The gamble had paid off, and a new problem had been deposited on the doorstep of the world

With the end of the war, the center of interest in the new field of atomic energy shifted from the plants and laboratories of the United States and the target cities of Japan to Washington, D. C., where men were wrestling with the decisions that would determine America's course in the atomic age. From the precedents of the wartime program, and from the hopes and fears of men for the future, they began the arduous job of building a legal structure that would contain the unleashed atom. Meanwhile, the nation's atomic energy program, which had been assembled to develop and produce the bomb, began to mark time while it waited to find out where it was going next. Funds were cut back, the British mission began to pack up and leave for home, and many of the scientists and technicians in the plants and laboratories left the program to return to the universities and industrial concerns from which they had been mobilized. During this period, the once dynamic program was held together, but that is about all one could have said for it, or expected of it.

But if things were quiet on the laboratory front, political activity in Washington was furious. The first development of record occurred four days after the formal Japanese surrender when a freshman Senator from Connecticut, Brien McMahon, introduced a bill for the domestic control of atomic energy. The Congress, which was waiting for the proposals promised by the President in his August 6 announcement on Hiroshima, tabled the bill.

The President's recommendations were forthcoming on October 3 in a message to the Congress on atomic energy. In this message the President said:

Never in history has society been confronted with a power so full of potential danger and at the same time so full of promise for the future of man and for the peace of the world. I think I express the faith of the American

people when I say that we can use the knowledge we have won, not for the devastation of war, but for the future welfare of humanity

"To accomplish that objective we must proceed along two fronts—the domestic and the international

"The first and most urgent step is the determination of our domestic policy for the control, use, and development of atomic energy within the United States"

Having thus described the objectives, the President proceeded to urge the Congress to establish "an Atomic Energy Commission with members appointed by the President, with the advice and consent of the Senate" He suggested that the entire program as it then existed be transfered to the new Commission, and that the Commission be authorized "to conduct all necessary research, experimentation, and operations for the further development and use of atomic energy for military, industrial, scientific, or medical purposes" He further proposed that the Congress declare it to be "unlawful to produce or use the substance comprising the source of atomic energy or to import or export them except under conditions prescribed by the Commission"

The President acknowledged that the measures he had suggested were drastic and far-reaching, but pointed out that 'the discovery with which we are dealing involves forces of nature too dangerous to fit into any of our usual concepts"

Relative to the world situation, he said "The hope of civilization lies in international arrangements looking, if possible, to the renunciation of the use and development of the atomic bomb, and directing and encouraging the use of atomic energy and all future scientific information toward peaceful and humanitarian ends I therefore propose to initiate discussions, first with our associates in this discovery, Great Britain and Canada, and then with other nations, in an effort to effect agreement on the

conditions under which co-operation might replace rivalry in the field of atomic power" Prophetically, the President commented "The difficulties in working out such arrangements are great" He might have added that the difficulties in working out a law providing for domestic control were also not small

On the same day that the President delivered his message on atomic energy to the Congress, an Administration bill providing for domestic control was introduced simultaneously in both Houses This bill, which had been prepared by the Secretary of War's committee, was introduced in the Senate by Senator Edwin Johnson and in the House by Representative Andrew May, chairman of the House Military Affairs Committee It became known as the May-Johnson Bill, and it provided for a part-time Atomic Energy Commission to which Army and Navy officers on active duty could be appointed The bill gave the Commission great powers and considerable latitude on how it was to exercise them

Almost as soon as the May-Johnson Bill had been introduced, a great controversy broke out in the Congress and across the land on the issue of civilian versus military control of atomic energy In the hot debate which followed, the May-Johnson Bill became the symbol of military control It was attacked from many powerful quarters, notably by the scientists who had been connected with the wartime program In a highly unusual invasion of the political arena the scientists organized themselves into a forceful pressure group that went to work to insure the civilian control of atomic energy in the United States

In acknowledgment of the controversy which raged around the May-Johnson Bill, the Senate on October 29 appointed a Special Committee on Atomic Energy, with Senator McMahon as its chairman, to make a full, complete and continuing study and investigation with respect

to problems relating to the development, use and control of atomic energy" This Committee began hearings the next month, and on December 20 Senator McMahon introduced his second bill, which became the basis for hearings which continued until the following April This bill provided for a full-time Commission whose members were to be allowed no conflicting military or business interests It also spelled out in considerable detail how the Commission was to exercise its enormous powers, and created a government monopoly in the field of atomic energy Just as the May-Johnson Bill had become the symbol of military control, the McMahon Bill became the symbol of civilian control, and the scientists adopted it as their standard So did President Truman, who in February wrote a letter to Senator McMahon calling for legislation essentially along the lines of the McMahon Bill

In the discussions which proceeded through the winter and spring of 1946, both within and without the hearing-room of the Senate's Special Committee on Atomic Energy, some basic areas of agreement began to emerge Everybody seemed to believe that the atom should be rigidly controlled by the government, everybody seemed to believe that this control should be exercised by civilians, and everybody seemed to believe that the military services should have a voice in the atomic energy program short of control

Ultimately it became clear that the only point of disagreement remaining was that of determining the precise limits of military participation In an effort to compromise this issue, Senator Vandenberg proposed an amendment to the McMahon Bill which would provide for the establishment of a Military Liaison Committee to work with the Commission on atomic energy matters of military interest But the proponents of civilian control found the powers this amendment bestowed upon the Liaison Committee to be far too great, and once again reacted vio-

lently Thus the compromise had to be compromised A final version of the Vandenberg Amendment was eventually hammered out, however, and the McMahon Bill, after a debate in the House which led to a strengthening of the security provisions, passed both Houses of Congress in its final form in July and was signed into law by the President on August 1, 1946

The new law, called the Atomic Energy Act of 1946, established a five-man Atomic Energy Commission, whose members were to be appointed by the President with the advice and consent of the Senate, and who were specifically prevented from engaging "in any other business, vocation or employment than that of serving as a member of the Commission"

The law bestowed enormous powers on the Commission, and furthermore ordered it to use them For example, the Commission was required to own all the materials from which atomic energy can be produced, all the facilities in which such materials can be manufactured, and all the patents related to the production and use of such materials In addition, the law directed the Commission to control through licenses and regulations all the minerals from which atomic energy materials could be produced, and all information related to atomic energy It also directed the Commission to conduct an extensive atomic research program, and authorized it, at the direction of the President, to develop and produce atomic weapons In other words, the law gave the Atomic Energy Commission a monopoly in the field of atomic energy, with the right to control all vital activities through direct ownership and management, and all other activities by means of regulations and licenses To help the Commission protect its secrets, the Congress provided for some stiff penalties for violations of the law, extending even to death or life imprisonment The law also ended

all co-operation with Britain and Canada in the important fields of weapons and atomic power

As a guide to the Commission in the exercise of its great powers, a declaration of over-all policy was included in the law which illustrates perhaps better than anything else Congress' awareness of the fateful decision it had made when it set the course of atomic energy control and development in the United States "It is hereby declared to be the policy of the people of the United States," the Act says, "that, subject at all times to the paramount objective of assuring the common defense and security, the development and utilization of atomic energy shall, so far as practicable, be directed toward improving the public welfare, increasing the standard of living, strengthening free competition in private enterprise, and promoting world peace"

To encourage and assist the Commission to exercise its great powers prudently and wisely, the law established a Joint Congressional Committee on Atomic Energy, composed of nine Senators and nine Representatives, and specified that the Commission "shall keep the Committee fully and currently informed with respect to the Commission's activities" It also established a nine-member General Advisory Committee, to be appointed by the President "from civilian life," to advise the Commission on scientific and technical matters, and the Military Liaison Committee provided for by the Vandenberg Amendment The Liaison Committee, which is appointed by the Secretary of Defense, consists of two representatives from each of the three armed services plus a chairman who may be either a military man or a civilian The Commission is directed by the law to 'advise and consult with the Committee on all atomic energy matters which the Committee deems to relate to military applications" and to "keep the Committee fully informed of all such

matters before it" The Committee, on the other hand, is instructed to "keep the Commission fully informed of all atomic energy matters" in the Defense Department The Committee furthermore is given the right to make written recommendations to the Commission and to appeal disputes through the Secretary of Defense to the President

Thus it was that America's approach to the postwar atom was established on the home front In essence, the approach was one of rigid government control, this control to be administered by civilian officials Assurance of the national defense and security was established as the principal goal, but it was also made clear that the newly reconstituted program was expected to work toward realization of the peaceful promise of atomic energy insofar as possible By mid-1946, then, the domestic course had been set All that remained was to name the people who would control the new program and to arrange for the transfer of the property and people of the Manhattan District to the newly established Commission

Meanwhile, the American position on the international front had also been set, and there was still some hope in the world that it, or something like it, might be put into effect By mid-1946 also, an Atomic Energy Commission had been established in the United Nations at the instigation of the United States, Great Britain, and Canada, joined by Russia, China, and France, and an American plan for international control had been developed and proposed to this Commission This plan, like the domestic plan, relied upon direct management as the only really effective means of control In essence, the plan called for the creation of an "International Atomic Development Authority' with power to manage directly all dangerous atomic energy activities in all nations, to conduct a research and development program in the peaceful applications of atomic energy, and to exercise loose control over

all non-dangerous activities The plan also called for a system of inspection to prevent clandestine activities by national governments, and a system of enforcement If such a plan were set up, the United States offered to dispose of its atomic bombs, give up all its activities in the weapons field, and turn over all of its atomic energy knowledge to the international agency

The basis for this plan was developed in the State Department in January, February, and March of 1946 by a Committee composed of Undersecretary of State Dean Acheson as chairman, and Vannevar Bush, James B Conant, General Leslie R Groves, and John J McCloy as members The Committee had the assistance of a Board of Consultants of which David E Lilienthal was chairman and Chester I Barnard, J Robert Oppenheimer, Charles Allen Thomas, and Harry A Winne were members The report issued by the Committee in March became known as the Acheson-Lilienthal Report, and it formed the basis of the American proposal made by the American Delegate Bernard Baruch to the United Nations Atomic Energy Commission on June 14, 1946 It was in this historic address that Mr Baruch prefaced his remarks with the now famous declaration "We are here to make a choice between the quick and the dead"

The world now knows what happened to that proposal Six months later something substantially the same was reported to the Security Council as the majority plan of the United Nations Commission, but it has never been adopted And neither has any of its modified successors, solely because the Russians and their puppets have not agreed with the majority of the members of the United Nations Atomic Energy Commission The Russians have said that they would consider such a plan to constitute an unwarranted invasion of their national sovereignty They have also said that they would prefer to destroy all of the world's atomic weapons first and have them re-

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and industrial work was performed by private contractors There were several hundred research contractors, several score important industrial contractors, and several thousand suppliers, performers of special services, and subcontractors of various sorts

4 The knowledge of how to produce atomic bombs

The new Commission very early decided to do its business, as the Manhattan District had done, through private scientific and industrial contractors, confining itself to policy direction and administrative supervision of the work This served two purposes it made available to the Commission the management and technical skills of American industry and science, and at the same time it served to spread knowledge about atomic energy through the American economy It also made it possible for the Commission to hold down the number of direct government employees Today, although the program has been expanded several times in size over what it was in 1947, the number of direct Commission employees has increased from 5,000 to but 7,000 Meanwhile, the number of contractor employees has increased from 50,000 to nearly 200,000

To carry out the responsibilities vested in it by the Atomic Energy Act, the Commission is organized roughly along the lines of a private corporation At the top, where policy is set, are the five Commissioners Next in line is the chief executive officer, called the General Manager Originally the General Manager was appointed by the President, he is now appointed by and is directly responsible to the five Commissioners Below the General Manager are a number of operating divisions, each with its own responsibility, such as military applications, production, research, reactor development, biology and medicine, and security Most of the Commission's day-to-day relations with its contractors are through field offices located at Oak Ridge, Hanford, New York, Chicago,

nounced as weapons of war, and then talk about how atomic energy might be controlled The majority, for its part, has rejected these somewhat unrealistic proposals on the grounds that they provide no safeguards against the surreptitious accumulation of a vast stockpile of bombs But all this has been but a symptom, not the cause, of the basic sickness in the world, a sickness that has led to the cold war between the East and West, the hot war in Korea and Indo-China, and the atomic armaments race between the United States and the Soviet Union As a result of this cold war and this armaments race, the American atomic energy program has been largely a weapons program carried on in secrecy and with the utmost urgency Progress has been made on the peaceful side, but, in the language of the law, it has never been the "paramount objective"

It was at midnight on December 31, 1946, that the newly established Commission took over the American atomic energy program from the Army's Manhattan District The Commission's inheritance included

1 Facilities with a capital investment of approximately $1,400,000,000, including a weapons research laboratory and a town of about 9,000 people at Los Alamos, New Mexico, important production plants, a research laboratory, and a town of about 36,000 people at Oak Ridge, Tennessee, an important production plant and a town of about 17,000 at Hanford, Washington, a temporarily housed research laboratory in Chicago, some important research equipment at the Radiation Laboratory in Berkeley, California, and research laboratories then under construction at Brookhaven, Long Island, Schenectady, New York, and Miamisburg, Ohio

2 A program that had about 5,000 direct government employees, both military and civilian, and about 50,000 contractor employees

3 A system under which virtually all of the scientific

mission itself, have done much to determine the scope and shape of the American atomic energy program as it exists today

But this is not a book about personalities It is not even a book about the Commission It is, instead, a book about the atomic energy program itself, a program that has been driven forward and expanded under a great sense of urgency as the only means by which the free world might compensate for the collapse of the great expectations once held for international control Mr Baruch in 1946 gave the world a choice between the quick and the dead That choice has not yet been made, but time has been bought in which it might yet be made correctly, and it has been bought largely through the effort described in the following pages of this book

Albuquerque, and wherever else there is a major atomic energy activity

The Commission's first Chairman was David E Lilienthal, former head of the Tennessee Valley Authority and co-author of the Acheson-Lilienthal Report which formed the basis of the American plan for the international control of atomic energy He served until his resignation on February 15, 1950, and was succeeded by the author, who occupied the office of Chairman from July 11, 1950, until his resignation in June 30, 1953 From February 15 to July 11, 1950, the Commission functioned under the acting chairmanship of Sumner T Pike, one of the original members of the Commission Besides Mr Pike, who had been a New England businessman and former Federal Power Commissioner, the original Commission was composed of the New York businessman and former Rear Admiral Lewis L Strauss, the atomic scientist Robert F Bacher, and the Iowa publisher William W Waymack As the years passed the composition of the Commission gradually changed, and by February 1952 it consisted of the atomic scientist Henry de Wolfe Smyth, the New York businessman and engineer Thomas E Murray, the former Air Force Assistant Secretary Eugene M Zuckert, the Ohio educator and engineer T Keith Glennan, and the author All of the last-named, with the exception of Mr Glennan, who resigned November 1, 1952, remain as members of the Commission at this writing

For most of the more than six years that the Commission has been in existence, the Joint Congressional Committee on Atomic Energy functioned under the chairmanship of the author of the Atomic Energy Act, the late Senator Brien McMahon, and the General Advisory Committee functioned under the chairmanship of the scientist given the most credit for developing the atomic bomb, Dr J Robert Oppenheimer These men and their colleagues, like those who have served on the Com-

depths of the earth Over the ages, many of the rocks in which the uranium was deposited have been worn away, and much of the uranium itself has been dissipated Some of it, however, by a mechanism not thoroughly understood, has been concentrated in tiny, inaccessible pockets in the desert sandstone The first uranium was found on the plateau at the turn of the century, but an intensive search is still going on to discover all of the places where the pocket deposits have been hidden away

One could hardly expect prospectors to burn up much energy or bankers to dig very deeply into their pockets simply to locate a mineral that up to World War II was used mainly as a coloring agent for porcelain and stained glass—and they didn't But in 1898 something happened that spurred the search for uranium deposits Radium was discovered by Mme Curie in Paris The connection between uranium and radium is that uranium always contains an infinitesimal amount of radium—about one part in three million—and, with radium selling at $200,000 per gram, the search in all parts of the world was frantic

One of the richest uranium-radium deposits was discovered at Joachimsthal, in Bohemia The Joachimsthal area has a colorful past It also has an active present and future, for it is today under the control of the Russians Let's have a look at it before we return to some of the uranium deposits on this side of the Iron Curtain

In both Saxony, which is today a part of Russian Germany, and Bohemia, which is today a part of Russian Czechoslovakia, there is an extremely rich mineral region It is located in the Erzgebirge range, which separates the two countries The region has been mined since the latter part of the twelfth century Originally mining operations centered on the tin field of Schonfeld In the sixteenth century, however, interest turned from tin to silver, and the mining activity shifted to Joachimsthal Silver mining proved so successful that a mint was established where

CHAPTER *ii*

Uranium Is Where You Find It

MAN has just begun to look for uranium Only a few years ago it was an unimportant metal used almost exclusively as a ceramic coloring agent No one cared much about it Today it is the essential feed material for the great atomic energy plants of this and other countries It is the base of the atomic energy pyramid and—it is hard to find

It is almost as though some wise Providence, distrustful of man's wisdom, had hidden it out For example, uranium from the famed Shinkolobwe Mine in the Belgian Congo must travel twelve hundred miles before it reaches a seaport and must then make a much longer ocean journey before it reaches the United States It was hidden—at least, not discovered—until 1915 Similarly, uranium from Canada s Great Bear Lake must travel fifteen hundred miles from its source—twenty-five miles from the Arctic Circle—before it reaches a railroad, and it can make this journey through icy waters but a few months of the year Providence kept the secret of this deposit until 1930

Such uranium as has been found in the United States is deposited for the most part in the sandstone of the Colorado plateau Far back in geological history this uranium was probably brought to the surface by volcanic action or the boiling up of hot ashes and liquids from the restless

when it comes to pitchblende Only in certain isolated areas in this country has it been found, and the amounts have been small But uranium does occur in the United States, where it appears usually in an ore known as carnotite, and behind this is a story

In 1898, when the Curies first extracted radium, it was from ores that had been mined in the Joachimsthal area A year later, however, a shipment of several tons of uranium-bearing ore arrived in France from the United States, and radium was extracted from it The world now had a second source of radium And if you should stop today for gasoline and a soft drink on the roadside a few miles from the mining town of Naturita, in southwestern Colorado, the elderly man who waits on you may tell you—and he would be telling the truth—that it was he who dug that ore and shipped it to Mme Curie The ore was named carnotite in honor of M Carnot, President of the French Republic

By 1912 the Colorado plateau led the world in the production of radium, and it retained that lead until the development of the richer Congo deposits The plateau, since then, has had its ups and downs In fact, due to the competition of the new African mine, most of the carnotite mines were forced to remain closed from 1924 until World War II

When we speak of the Colorado plateau we mean an area of approximately 130,000 square miles located in Eastern Utah, northwestern New Mexico, northeastern Arizona, and Colorado west of the Rocky Mountains It is on erosion-scarred land of many colors, a land of sharp-walled mesas, deep canyons, and little water Roads are few, steep, and rocky The uranium-bearing ore is found most frequently in the places that are most inaccessible—the canyon walls near the tops of the mesas It is here that prospectors tap away with hand picks and await anxiously the click of the Geiger counter And when the

silver coins, called *Joachimsthaler*, were struck The word *Joachimsthaler* was later contracted to *Thaler*, a name that is still used for certain coins in various parts of the world and, incidentally, is the root of the American word *dollar*

Three hundred years later the mines of Joachimsthal turned up a little-known mineral, pitchblende, in heavy blue-black veins containing uranium Uranium had come into demand because of its use as a coloring agent The mines flourished With the discovery of radium at the turn of the last century, international attention was again focused on the mines, which for a period enjoyed a world monopoly in that elusive and extremely costly element

Today some of the most productive pitchblende mines in the fabulous Erzgebirge range are located at Joachimsthal There are three of them One characteristic of the mines is that silver is particularly plentiful in the upper workings At the middle levels, however, one finds cobalt, nickel, and bismuth The pitchblende ore with its uranium is found most abundantly in the lower workings Although the richest ore was probably taken out long ago, thousands of slave laborers are today fervently scratching away in these lower levels, extracting the remaining ore to feed the Russian atomic effort Additional thousands are busy in the many mines of Saxony where there is an apparently plentiful supply of lower grade ore What kind of effort all this goes to support will be discussed in a later chapter

There is one striking similarity among the uranium-bearing ores of the world's three most famous deposits the Joachimsthal, the Shinkolobwe, and the Canadian deposits of the Great Bear Lake In each the ore is the high-grade source of uranium, pitchblende, and it is found in association with cobalt and nickel and certain other base and precious metals

Unfortunately, the United States is a have-not nation

Airborne radioactivity-detection equipment, mounted on helicopters and light aircraft is being used to develop a simple, fast way of covering this vast area, and the results have been encouraging But even this process presents problems Since these instruments, known as scintillometers, which are more sensitive than Geiger counters, are designed to pick up gamma radiation from uranium deposits, and since the intensity of these radiations decreases to fifty per cent at about four hundred feet, it means that the planes must fly low—in the neighborhood of five hundred feet Better results are obtained by flying at even lower altitudes, but flying along the canyon walls through tricky air currents is at best a hazardous business More sensitive scintillometers, however, are being perfected which will remove some of the hazards of aerial survey

Once a discovery is made, the miner must have a place to sell his ore within hauling distance of his mines and he must be able to sell it at a price that will give him a profit As ore bodies are discovered, the Atomic Energy Commission must, therefore, encourage private industry to erect ore-buying stations and processing plants There are already fifteen points scattered throughout the plateau where ore can be delivered and sold, and the Commission publishes the guaranteed prices paid for ores delivered to any of these stations

The Commission has never gone into the business of mining ore But it has, by offering bonuses, by its diamond-drilling programs, and by the establishment of prices and hauling allowances, furnished incentives to private mining interests With one exception, it has built no processing plants in the region All the others have been built entirely by private concerns with private capital Because of the various incentives offered by the Commission, however, plus its own drilling program, mining activity on the plateau has increased rapidly in recent

click comes, it is here that the first exploratory holes are dug, back in the sandstone layers of the tableland An ore body is considered large if it contains a few thousand tons—not tons of uranium but tons of ore, for the ore in such pockets contains only about three to ten pounds of uranium to each ton of ore

This seems a hard way to find uranium, and fortunately there is another This involves boring down from the mesa top with diamond drills In this way one can take samplings of the ore bodies that slant back into the mesas from the walls The extreme irregularity of the deposits and the risks involved in exploring for low-grade ores, however, make extensive drilling impossible for other than large companies and government agencies In 1948, therefore, the Atomic Energy Commission, with the assistance of the U S Geological Survey, commenced a systematic diamond-drilling program, guided by expert government geologists The drilling is actually performed by private companies working under contract to the government on the basis of so many dollars per foot Since the cost would be prohibitive if one were to drill systematically the whole vast area of the Colorado plateau, emphasis has been placed on the mineral belt in the southwestern part of the State of Colorado

But even diamond drilling is a hard way to find ore One of the greatest problems connected with prospecting on the plateau, whether by "sourdough" or diamond-drilling methods, is water In the spring, water is readily available, but in the late summer and fall it becomes scarce and hauls of eight to ten miles are common

Is there no easier way to find uranium? Would it be possible, some asked, to install a powerful counter in a plane and fly it over this rugged plateau country? Where the counter didn't register, the area could be forgotten Where it registered, careful ground exploration could be undertaken Recently such devices have been employed

who had only the advantage of a booklet describing the characteristics of various uranium-bearing ores

In countries where there is no uranium program, the United States must be prepared, when new deposits are found, to make available drilling tools and mining and concentrating equipment It must be prepared to lend money and furnish other inducements in order to get from the bowels of the earth—very fast—the precious metal that may spell the difference between a slave and a free world

Is the Commission garnering all the uranium ore that is available to the Western World? The answer is "no" Someone has calculated that one part in each 250,000 parts of the earth's crust is uranium On this basis uranium is a thousand times as plentiful as gold, a hundred times as plentiful as silver, and almost as plentiful as lead or zinc In one sense, this is encouraging, but it is also deceptive Although uranium is literally everywhere (I have heard it said there are several pounds in the Washington Monument), most of it is simply not concentrated enough to mine it economically So, unless we can secure uranium either from high-grade deposits or as a by-product of some other mining operation, the cost of extraction is far too great to be seriously considered

Let's take an extreme example It is well known that magnesium is extracted economically from sea water It is also known that in one cubic mile of sea water there are about five tons of uranium We could get this uranium, but let us consider for a moment what it would cost In the first place, magnesium is much more prevalent in sea water than is uranium It has been estimated that if we were to build a plant the size of a normal, economical magnesium-sea-water processing plant, we would get on the order of only fifty to seventy pounds of uranium from it per year Two scientists several years ago calculated that to obtain uranium from sea water at a rate of one hundred tons per year, enough to make it a mildly inter-

years In 1946 the plateau was practically a ghost camp with a little vanadium and no uranium production There were only fifteen individual mining operations employing a total of fifty-five men The ore coming out was chiefly vanadium Today there are over three hundred uranium-mining operations

In recent years the known limits of the mineral belt of the Colorado plateau have been widened In 1951, for example, a new discovery was made at Grants, New Mexico, close to the right-of-way of the Santa Fe Railroad and in full view of a well-traveled highway That discovery was made by a Navajo Indian, Paddy Martinez, at Haystack Mountain, north of Bluewater He had seen some ore samples at a trading-post and recognized them as being similar to rocks he had seen near his homestead The area is being developed, a processing plant is being erected with private funds, and new discoveries are being reported daily

Other interesting finds have been made in states as far removed from the old Colorado mineral belt as North Dakota One discovery follows another All such discoveries will not be made by scintillometers carried in airplanes They will not all be found by diamond drilling Some will be found by persons who have not had the benefit of a degree in engineering or experience in prospecting for minerals Some will be found by "accident," and it is one of the Commission's responsibilities to encourage such "accidents" by spreading the word concerning uranium To this end, the Commission prepared a booklet entitled *Prospecting for Uranium* Since 1949 the Government Printing Office has sold approximately 100,000 copies of this prospector's handbook The Commission also has the responsibility of encouraging the distribution of similar information by the governments of other countries, remembering that a recent discovery in the Rum Jungle of Australia was made by a prospector

so overwhelming that no aggressor would dare provoke a conflict, if we are to be able to exterminate any aggressor so foolish as to start a war (and we must remember that such dictators as Hitler, Mussolini, and Tojo were foolish to this extent), it becomes clear that we cannot rely solely on the so-called "rich" deposits We must seek uranium where it can be mined economically in conjunction with other valuable minerals This we have done, and we turned first to South Africa, whose economy depends greatly upon the production of gold

For many years the gold produced by South Africa has been extracted from an ore containing small quantities of uranium The amount of ore processed to extract the gold is tremendous Consequently the uranium that might be extracted could be significant in amount The problem was Could we develop a process which would extract from such ores the uranium as well as the gold? American, British, and South African scientists set to work to develop such a process, and today it is in operation We are getting this uranium

In Florida and in the Northwest there are extensive deposits of phosphate rock These contain uranium The uranium content is very low, but the enormous tonnages of rock available contain important quantities of uranium and other valuable materials, including the phosphate itself, which is useful in the manufacture of fertilizer and certain chemicals Overlying these deposits in Florida is a type of soil called "the leach zone' which also contains small quantities of uranium, as well as some phosphate and alumina from which aluminum is made

We could, if we had to, supply all the needs of the atomic energy program from these sources But this uranium, because of the low grade of the ore, would cost several times as much as the uranium in Canada, the Congo, the Colorado plateau, and South Africa, and in the process of getting it we might have to dig up a sub-

esting source, we would need a plant capable of processing 12,000,000 tons of sea water per hour The cost of such a plant was estimated at about 150 billion dollars We could do it, to be sure, but what would be the affect on our economy? What would become of the rest of our defense effort?

When we speak of Canada and the Congo and Colorado as containing "rich" deposits, we have perhaps not chosen a very descriptive word Only in a relative sense are they "rich" It takes scores of gondola cars loaded with ore from such deposits to give us the uranium needed to make one atomic bomb Actually, we mine some ores that are so low in grade that it requires *hundreds* of gondola cars of ore to produce the core of one bomb So we must place the greatest possible emphasis upon exploration—exploration for "rich" deposits Wherever members of the Commission have traveled in foreign lands we have preached the gospel that the security of the Western World may depend upon such a simple thing as people keeping their eyes open Every American oilman looking for "black gold" in a foreign jungle is derelict in his duty to his country if he hasn't at least mastered the basic information on the geology of uranium And the same applies to every mountain climber, every big-game hunter, and, *for that matter, every butterfly catcher*

These 'rich" deposits have been made available to the United States by our friends, the United Kingdom, Canada, and Belgium Developing even these deposits cannot be undertaken in a day, nor without money and critical materials The Atomic Energy Commission has made commitments—contracts to buy uranium—which will bind the American taxpayer over a period of several years But without such commitments to friendly nations the American atomic energy program could not exist, much less expand

But if the United States *is to possess atomic superiority*

world's richest uranium mine He must know also that there are people behind such an operation, courageous and friendly men like Edgar Sengier of the Union Minière, men who deal in "blue chips" but who have yet never haggled when the defense of the Western World was the issue He must be able to picture barges coursing their way south from the Arctic Circle, carrying the ore of the Great Bear Lake, and in so doing he must see that ore being lifted from those barges, trucked across portages to the next waterway, there again to be reloaded To have any appreciation at all of the problems involved in the search for this elusive metal, he must be able somehow to picture a grizzled prospector in the lonely reaches of the Colorado plateau tapping away at an outcropping somewhere high on a mesa, Congressmen urging on behalf of the miners that the precipitous rocky roads of the region be improved so that they may get their ore to market, miners asserting that the procedure for assaying their samples is unfair, colleges insisting that their scientists be given a grant to work on the problem of extracting uranium from low-grade ore, geologists leaving the Commission's employ when appropriations are cut, diamond drillers insisting that with inflation the price per foot of drilling must be increased, Indians of the Navajo tribe meeting in sober council to work out some arrangement whereby this new birthright discovered on their reservation will not be sold for a mess of pottage

Yes, one must be able to picture, if even in a very vague fashion, five Commissioners in Washington, D C, attempting to find a formula whereby an incentive can be provided to explore and mine, without at the same time pouring taxpayers' money down some pack-rat hole in the Western desert And he must understand the strong and understandable proprietary feeling which prevails in so many countries of the world, such as India and Brazil and Australia, countries which are most reluctant to deplete

stantial chunk of Florida real estate As it is now, we are getting small quantities of uranium from phosphate rock as a by-product of fertilizer production

In a final emergency we could process the uranium which occurs as a very minor constituent in the vast deposits of the so-called "Chattanooga shales" in Tennessee, West Virginia, Ohio, Indiana, and Alabama, but the cost would be very great, even greater than that of working the phosphate deposits Long before we are backed into such a corner our stockpile of atomic weapons will be great enough to deter any reasonable would-be aggressor who knows or suspects the facts But we cannot assume that a would-be aggressor will be reasonable Therefore, we can take no chances We must be prepared with the necessary scientific knowledge to enter upon this costly venture of developing the very low-grade ores if it becomes necessary We are so prepared

The political and diplomatic problems involved in getting uranium have been great The problems involved in stimulating prospectors to find the ore, and miners to mine it, have been even greater The problems which the scientists have had to tackle in order to get from the earth's bowels something which could be quickly fed into the great processing and production plants of this country have been greater still And the problems which remain—those of explaining to the American people, and more particularly to American industry, what this all means, both from the standpoint of the defense program and the ultimate peacetime uses of the energy which this metal has locked within it—are still greater

If one is to think upon the problem of getting uranium, he must, for any understanding of it at all, have in his mind's eye many pictures He must, for example, be able to picture Shinkolobwe, deep in the brushland of southeastern Katanga Province in the Congo He must picture a great open gash in the earth which represents the

CHAPTER *iii*

The Production Line: Ore to Bombs

We have seen where uranium ore comes from and how we go about obtaining it Now let us see what we do with it after we get it

It is a long and intricate route that uranium must travel from the mines of the Belgian Congo, northern Canada, South Africa, and the Colorado plateau to the secret locations where atomic bombs are stored It is also an expensive one

More than three fourths of all the money and materials and skills that America has invested in her atomic energy program has gone to build up the plants and laboratories that uranium must pass through along the way to a bomb This is the atomic energy production line In some ways it is similar to the production lines that lead from the Mesabi iron range of northern Minnesota to your kitchen refrigerator, and from the Texas oil fields to the gasoline tank of your car But in many other ways it is completely different, unlike anything else that is done in industry and unlike anything else that has ever been done before in the world

The atomic energy production line includes a myriad industrial processes, ranging all the way from such relatively simple and straightforward operations as the grind-

those natural resources which may someday spell for them great future blessings in terms of cheap power It seems obvious to me that if we are to continue to get ore from abroad we must be prepared also to give up certain information and equipment and technology which will aid these countries in the development of their own atomic programs But there will be more on this in the chapter on "The International Atom" Meanwhile, let us see what happens to the ore after it is mined and passes into the hands of the Atomic Energy Commission

It is your job to get your ore to Durango Let us say you haul it by truck, first across the dry dirt roads that criss-cross the wind-swept plateau, and finally along one of the new paved highways the government has built to open up the uranium country

When your ore arrives at Durango, it is first weighed, sampled, and assayed The assay determines the uranium content, and it is very precise because it not only determines the price that is paid to you, but also forms the basis for the strict accounting that is kept of the uranium along the rest of its way to the bomb stockpiles

You are paid for your ore according to the amount of uranium it contains If it also contains vanadium, as carnotite frequently does, you are paid for that too, not because the Commission wants it, but because it is another valuable metal required in the defense program of the United States In addition to the price paid to you for your ore, you are also paid an allowance to cover the cost of hauling it to Durango and an allowance to cover the cost of developing your mine And if your mine is a new one, you may also be paid a bonus of from $1 50 to $3 50 per pound of uranium for the first ten thousand pounds you deliver Since the price paid per pound is always at least equal to the bonus, you can see that it is possible to receive as much as or more than $70,000 for ore containing ten thousand pounds of uranium

After you have left your ore at Durango, it is under the rigid control of the Atomic Energy Commission Most of the time the uranium it contains is actually in private hands—those of the contractors to the Commission who do the processing work—but the government never loses sight of it and never lets it out of its own control

Let us say that the ore you sold at Durango is the lowest grade the Commission will buy This means that a ton of it contains two pounds of uranium metal The first job, then, is to isolate that uranium and remove it from the

ing and crushing of ore to the transmutation of elements—the dream of the ancient alchemists who vainly sought to change common metals into gold But the Atomic Energy Commission is after something far more valuable than gold It is after the materials, known to the scientists as "fissionable," that pack more energy into a pound than coal does into a thousand tons

To get these substances the Commission must take ore that is measured in carload quantities and send it on a journey from which emerge only minuscule amounts of material measured in terms of grams To gain a feeling for what this journey is like, let us select a particular quantity, say a ton, of ore and follow it all the way through—seeing what happens to it and glimpsing the facilities it passes through along the way

Let us say that the ore we wish to follow belongs to you Let us say you found it high on a mesa in the lonely distances of the Colorado plateau where a splash of yellow among the many hues of that colorful land revealed the presence of carnotite Let us say the click of your Geiger counter confirmed your discovery and that you staked out a claim, just as you would if you found gold or silver or copper Although the ore belongs to you—not to the government—you cannot sell it or give it to anyone except the Atomic Energy Commission or someone approved by the Commission

But there is a good market for your uranium just the same The Commission wants it badly, and will buy it from you even though it contains only two pounds of uranium to each ton of ore

So you decide to sell your ore to the nearest ore-buying depot, of which there are fifteen in the Colorado plateau area operated by either the Commission or one of its contractors Let us say that the nearest depot to you is the one at Durango, Colorado, operated by the Vanadium Corporation of America under Commission contract

It is your job to get your ore to Durango Let us say you haul it by truck, first across the dry dirt roads that criss-cross the wind-swept plateau, and finally along one of the new paved highways the government has built to open up the uranium country

When your ore arrives at Durango, it is first weighed, sampled, and assayed The assay determines the uranium content, and it is very precise because it not only determines the price that is paid to you, but also forms the basis for the strict accounting that is kept of the uranium along the rest of its way to the bomb stockpiles

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clay, sandstone, and conglomeration of other materials which comprise the rest of the ore The effort to do this begins right at Durango, for the government does not want to pay to ship any more of the material than is necessary to the next stage in the production chain The methods used to recover uranium from ore are not unique in industry—similar methods are also employed to remove such metals as copper, gold, and silver from the ores in which they occur But, even so, it is no easy job, particularly when one remembers that the uranium is scattered through the ore in microscopic particles smaller than the point—not the head—of a pin

As the first step in the processing chain, your ore is placed in a giant crushing machine From there it goes to a grinder where it is ground into small particles similar to the finest grains of sand Then it proceeds into an industrial inferno where it is roasted with salt at temperatures of up to 1,000° F, percolated with water, dissolved in acid, heated and reheated, dissolved and redissolved, dried and redried Ultimately, after several days of this, the uranium emerges in the form of a fine grayish-black powder that is a compound of uranium and oxygen It is called "black oxide" The yellow of the carnotite is gone

Out of your original ton of ore we now have left only a little more than two pounds of material consisting of uranium, oxygen, and some impurities The rest of the ore, minus the vanadium it may have contained, has joined the vast hills of "tailings" which grow beside the Durango mill

Now, although we have something which approximates pure uranium, it is not anywhere near pure enough to serve the purposes for which the Atomic Energy Commission wants it It may contain only about one per cent of impurities—boron, for example—but this is more than enough to make it useless for the atomic energy program

So the black oxide is shipped on to the next stage in

the production chain where the much harder job of pulling away the elements that cling so tenaciously to uranium is begun For this operation, your uranium may be sent to the Commission's new Feed Materials Processing Center at Fernald in southwestern Ohio, or it may go to one of the great chemical plants which sprawl over the industrial areas of our midwestern cities, and where only a guard force and a fence around a building or two show that something occurs there to which the public is not invited

No matter to which location your uranium is shipped, the things that are done to it are generally the same Let us say, then, that it goes to the processing center at Fernald The buildings and equipment at Fernald are owned by the Commission, but the operation is carried on by a private company, the National Lead Company of Ohio, employed by the government to perform this specific job

Here your black oxide is put through the usual initial steps of weighing and analyzing, and the results must check with the last report from Durango or an investigation is set in motion immediately to find out why they differ

Once these preliminary steps are out of the way, however, your black oxide re-enters the world of burning acid that it so recently left at Durango If you could catch a glimpse of it at one quiet moment along this segment of its journey, you would see that the black powder which had arrived at Fernald was now a bright orange But this would be only a stage, and if you waited until it finally emerged its color would be a deep brown This material, still in the form of fine powder, is called "brown oxide," and it differs from black oxide not only in its chemical composition, but also in one other very important respect by now the uranium in it is pure

One might think that, now that we had a chemical compound containing pure uranium, we would be close

to the end of our journey We are not Actually, we have hardly begun Our uranium, for example, has not yet even seen any of the great atomic energy plants at such places as Oak Ridge, Hanford, Savannah River, or Paducah The reason for this is that natural uranium, even in its purest form, cannot be used in a bomb What the Commission wants for a bomb are the fissionable materials that uranium can be made to produce

There are two of these One is a very special kind of uranium known as uranium-235, which occurs naturally but very sparingly—less than one per cent—in normal uranium metal Our problem here is to get this "235" out, and no ordinary industrial methods can be used because '235" and normal uranium react to all chemical processes in the same way

The other fissionable material is plutonium This does not occur in nature at all, not at least in any amount worth mentioning It is not in uranium and it is not in anything else But it is an element, like gold or lead or uranium, and to make it man must practice the fantastic art of transmutation for which the alchemists sought so long in vain The problem here, then, is to change—not lead into gold—but uranium into plutonium

To see how this is done, let us return first to the slightly more than two pounds of brown oxide that has emerged from your ton of ore Brown oxide is a simple chemical compound It consists of one part of uranium bound chemically to two parts of oxygen But, so long as the oxygen is present, the uranium cannot be used to produce either '235" or plutonium, and the oxygen cannot be removed except by supplanting it with something else

So back the brown oxide goes to the chemical baths, and this time it emerges as a light green powder known as 'green salt The oxygen is gone and in its place is fluorine To get a rough idea of how difficult this operation is, one need only recall that, of all the elements in the

world, fluorine is probably the the most corrosive It will dissolve glass, severely corrode most metals, including stainless steel, and ignite all organic materials such as wood, clothing, many plastics, and oil It will even react with water, and if it is introduced into overly moist, confined air, it will explode violently

Although the process for producing it is a delicate and potentially hazardous one, green salt itself is a stable, relatively harmless compound It is of very great value to the atomic energy program, for it marks the starting point in the manufacture of both plutonium and uranium-235 It is here, therefore, that the road divides, one fork leading to the bomb stockpiles via the great plutonium plants at Hanford and Savannah River, and the other via the huge uranium-235 plants at Oak Ridge, Paducah, and Portsmouth

Let us say that half of your uranium goes in one direction and half in the other On a purely arbitrary basis, for both are important, let us first follow the route marked "plutonium"

To produce plutonium, the material that is needed is pure uranium metal This metal is rather simply obtained from green salt in one clean chemical operation that removes the fluorine from the salt and leaves pure uranium in a molten blob at the bottom of the reaction vessel After it has cooled, you can now for the first time see your uranium in all its pristine beauty—a bright, very heavy, hard material not unlike lead in weight and not unlike nickel in color Your uranium, although mildly toxic if inhaled or eaten in the form of dust, is now safe to touch and hold And it is not unlike many other metals, such as silver, lead, and gold, except that it will form a grayish-black rust very rapidly along its surface if exposed to the air for any appreciable period of time When it is recalled that as recently as 1942 there was not enough purified uranium in the world to fill a small briefcase, it is evident that

the large-scale production of this metal is no mean achievement

Now the chemist is through with your uranium for a while, and it passes into the hands of the metallurgist and machinist Here, with other uranium, it is cast into ingots, rolled into long rods, and then cut into relatively short cylindrical bars To prevent deterioration through the formation of rust, it is sealed as soon as possible into tight-fitting aluminum cans It is now ready for the plutonium production plant

Let us say that one of your two pounds of uranium has found its way into a can destined for one of the futuristic plutonium plants at Hanford on the banks of the majestic Columbia River The Hanford plant was built during the war by the du Pont Company It is now operated by General Electric under contract to the Commission

When it arrives at Hanford your uranium is ready for one of the most exciting and mysterious parts of its journey on the way to a bomb You can feel the importance and mystery in the air when you visit the government-built town of Richland, which lies just outside the 400,000-acre reservation where the widely separated plutonium plants are located

Richland is an "open" city You can drive into it and stay at the hotel You can walk down its streets, shop in its stores, go to its movies, and visit in its homes It is a pleasant, busy community of about twenty thousand people, with children playing along its sidewalks, and bakery and laundry trucks mingling with the private cars which line its streets Except for its freedom from smoke and dirt, it is not unlike many other towns of similar size throughout the country

But the imprint of the atomic age is upon it just the same You can feel it when you walk by the white frame building which faces the mall and see the sign in front which says simply "U S Atomic Energy Commission,"

Hanford Works" You can feel it when you look out in the direction of the plant area and see the small patrol plane endlessly circling around the periphery of the controlled reservation And you can feel it when you notice the road leading north, out past the city limits, past the guards and the gate marked 'Prohibited Area," and into the barren acreage where the gray shape of one of the plant areas looms faintly in the distance

It is into this forbidden region that your uranium now must go, there to be transmuted, at least in part, into the precious man-made element plutonium

The process by which this transmutation is accomplished is unique in industry It is not a chemical process, such as the burning of coal or the manufacture of synthetic rubber It is a *nuclear* process and takes place in a huge, box-shaped pile of graphite and uranium which is several stories high and is known, appropriately enough, as a "nuclear reactor"

The reaction which occurs in a nuclear reactor differs from a chemical reaction in that it involves, not such "large' particles of matter as molecules and the outer shells of atoms, but rather the hard, unimaginably minute inner core of an atom known as its nucleus, about which the outer particles revolve as planets around the sun For a very long time the atom successfully guarded this inner, inviolate area from the increasingly persistent encroachments of man As a matter of fact, it was only a few years before the advent of the atomic energy program that man first penetrated this inner heart, and even then he was able to do so with only an atom or two at a time, aided by mammoth and ungainly machines bearing such Buck Rogerish names as "cyclotron," betatron,' and "Van de Graaff generator"

This is the world of the Hanford process, of the nuclear chain reaction It is the world of the proton and neutron, particles of matter so small that more than a hundred

million of them would not make a speck large enough for the human eye to see And it is the world of the physicist and radiochemist—the men of science who ceaselessly probe the mysteries of the nuclei of atoms, and whose researches first produced the knowledge that every so often a uranium-235 nucleus will split in two, releasing neutron "bullets" which, if they can be made to strike other "235" atoms, will in turn cause these to split in two This is the nuclear chain reaction—the process upon which the entire atomic energy program is built

It was also the physicist who discovered that these neutron bullets which shoot out a splitting "235" atom will, if they can be made to strike the nucleus of an ordinary uranium atom, called uranium-238, cause it to undergo the miracle of transmutation In the nuclear reactors at Hanford, billions of such miniature atomic explosions are taking place, and billions upon billions of neutrons are being released to perform their vital work of changing normal uranium into plutonium

In many ways we can think of this reaction as a nuclear fire In fact, people who work with reactors often refer to them as nuclear "ovens" in which they "cook" uranium But the "fire" that is raging inside is not at all like an ordinary coal or chemical fire For one thing, it needs no oxygen—only neutrons—to make it go For another, unlike a chemical fire, you can't see or hear it The billions of miniature explosions are so small and so dispersed among the uranium and graphite that they cannot be detected by any human sense of hearing But, just like a chemical fire, this nuclear fire produces heat and to keep the reactor from melting, it must constantly be cooled by water flowing through a network of thousands of tiny crevices

There is another important difference between a nuclear fire and an ordinary chemical one, and that is the production by the nuclear reaction of invisible, intensely lethal rays that must be guarded against by a great shell

of lead and concrete, many feet thick, surrounding the uranium and graphite core

This is what you see when you look at a reactor—the forward face of the lead and concrete shell, punctured by hundreds of small, round holes, about the size of a silver dollar into which the cylindrical cans of uranium are fed at loading time It is a strange and awesome feeling to walk into a reactor building and see this huge face of concrete looming above you Only the soft hum of the ventilating equipment and the pumps that push the water through the reactor break the impressive stillness In some ways it is not unlike entering into the purposeful tranquility of an operating-room where the dramatic battle between life and death is joined

This is the throne room where King Atom reigns supreme This is where he practices his mystic arts in the privacy of his concrete cell Man has already contributed his part by calculating just the right configuration of uranium and graphite needed to release the hidden forces of the atom and by building the pile to these specifications Now man's principal interest is to control the reaction so that it proceeds to just the right level to produce the most plutonium possible He does this, with the aid of machinery, by manipulating metallic bars that absorb neutrons When the atomic fire gets too hot, he pushes the bars in, thus absorbing sufficient neutrons to slow down the reaction If the fire gets too cold, he can remedy that by pulling the bars out

To see how this is done, let us walk into the control room from which man s influence over the nuclear reaction is directed If you have ever been inside a television control booth, you will have a rough idea of what this control room is like Three walls consist of great banks of instruments with flashing red and green lights, dials with hands that sweep interminably, and mechanical pencils that draw lines, day in and day out, on rolling

sheets of graph paper Before one wall there is a panel of instruments arranged in front of a chair and looking much like an organ console

Here, for the first time in the reactor building, we encounter people—perhaps a man or two in a white dust coat, and maybe a girl They are watching the lights and the graphs and the dials Occasionally one will touch a lever or a button Occasionally one will speak briefly into a telephone or write something down on a pad of paper It is all very quiet and businesslike, and, to the uninitiated, it is an electronic maze he cannot hope to understand

From the control room you have a good view of the loading face of the pile Let us say it is loading day The pile is shut down, the control rods are in, the "fire" is temporarily quenched Let us say that your pound of uranium, sealed with other uranium in an aluminum can, is being loaded into the reactor Together with thousands of other cans, it goes with the aid of machinery into one of the many small, round holes that lead through the concrete and lead shielding to the reactor core Once in the reactor, it rests in tubes around which cooling water is circulated and which are separated by solid cubes of graphite The graphite is there because it helps to direct the neutrons released in the atomic fire to their ultimate goals in uranium-238

After your uranium is inserted in the pile, the holes leading through the concrete shell are sealed with lead stoppers, the control rods are gradually withdrawn, and the pile of uranium and graphite bursts into nuclear flame There your uranium remains for a period of several months, "cooking,' undergoing its own strange kind of metamorphosis as minute particles in it change from one basic element into another

When the uranium is 'done'—that is, when as much as is efficiently possible has been changed into plutonium—it is pushed out the other side of the reactor into a canal

filled with water to a depth of thirty feet This water absorbs the deadly rays now emanating from the contents of the aluminum can

Months of nuclear cooking have made the uranium "hot"—in a nuclear sense But there is no visible change in the aluminum can, and, if you could see it, the uranium itself would not look vastly different The particles that have changed into plutonium are individual atoms widely dispersed throughout the uranium, and they could not be seen even with the most powerful microscope But the can is "hot' even so, and although you would not feel this radiation immediately by touching it, the excruciatingly severe burns that would shortly appear on your hand would tell you that you had dared to defy one of the basic forces of the universe

The can containing the uranium and plutonium is now allowed to "cool" for a month or more in the canal You can walk down to this cement-lined channel and look over the railing There, deep below you, amid the subterranean equipment used to transport the cans away from the reactor, you can see one of the most eerie and beautiful sights of the atomic age—the cold blue glow that surrounds each can of uranium and that marks the effect of its intense radioactivity on the water

From the canal your can of uranium goes to another building and back into the hands of the chemist Only a fraction of the uranium has been changed into plutonium, and the problem now is that old familiar one of separation—to get the plutonium out This, of course, is a chemical problem, for uranium and plutonium, being different basic elements with different chemical properties, can be separated by conventional chemical means But we must remember that your metal now is intensely radioactive and cannot be handled in conventional ways So the entire chemical separation process, including the handling of burning acids and the transfer of materials

from one cell to another, must be carried out by remote control behind great lead and concrete barriers

This, as might be imagined, is an immensely difficult job, even when performed with the aid of such modern devices as mechanical hands, mirrors, periscopes, and television But it is done nevertheless, and when it is completed we have, at long last, the precious man-made element we have been after all along—plutonium

Pure plutonium metal looks much like pure uranium, or, for that matter, like pure nickel, silver, or chromium It is heavy, like natural uranium, but differs from it in one very important respect—if it is brought together into what the scientists call a "critical mass" it will explode like an atomic bomb As a matter of fact, it would *be* an atomic bomb It is also poisonous, and, to make matters still worse, radioactive The scientist who named plutonium quite evidently knew what he was doing, for 'plutonium" is also the ancient name of the vapor-dimmed entrance to Hades It is obvious from the properties of plutonium metal that it must be handled with the utmost precision and the most painstaking kind of care

From the Hanford chemical-processing plant your uranium, or rather now, your plutonium, is taken deep behind the cloak of security to the secret locations where it is fabricated by machine-shop methods into shapes that can be used in the cores of bombs Farther along the production line it meets and is assembled with the non-nuclear components of the bomb, and the whole goes into the national weapons stockpile, ready for use against an aggressor in time of war

This plutonium—of which only a fraction of an ounce has been produced from the original ton of uranium ore—is for all practical purposes a stable, permanent material of immense value, not only as explosive-weapon material, but also as fuel for atomic power plants Any time we decide that we need it more for power than we

do for weapons, we have only to take it out of the bomb stockpile and put it to peaceful use

You will recall that when we set out on the road marked "plutonium," we left behind approximately a pound of green salt destined to travel the uranium-235 route to a bomb Now that we have had a glimpse of the plutonium process, let us go back to Fernald and follow this other batch of green salt on its way to a bomb

The process is quite different There is, for example, no transmutation involved, and no nuclear reaction But it is no less unusual, no less fabulous, and no less difficult

The differences between the two processes stem partly from the fact that uranium-235, unlike plutonium, exists in nature It is present in all natural uranium, and it is therefore present in the uranium in your green salt The problem is to get it out

To acquire some idea of the magnitude of this job, it must first be understood that uranium-235 is an extremely rare substance Although it exists in natural uranium, it is there in a ratio of only 1 to 140—in other words, there is but one part of "235" to each 140 parts of the normal uranium known as uranium-238

It must also be understood that uranium-235 is identical, chemically speaking, with uranium-238 This means that it melts at exactly the same temperature, and that it reacts with all chemicals in exactly the same way Thus, if you were to place a small quantity of "235" in one test tube and an equal quantity of "238 in another, and were to pour in, one at a time, every other substance known to man, the reactions that would take place in each test tube would be identical As you can see, this poses a rather difficult problem when one wishes to develop an effective means of separating the two

It was this problem of separation that occupied the attention of a good many of the scientists connected with the Manhattan Engineering District during the war Be-

cause there is no chemical difference between uranium-235 and 238, the scientists quite naturally turned to its nuclear differences to find an effective separation process

There is, of course, one spectacular nuclear difference between "235" and "238" the nucleus of a "235" atom will split in two when struck by a neutron, whereas the "238" nucleus will change into plutonium But this is hardly a useful means of separation, for, even if we could shoot a stream of neutron bullets into a piece of uranium, we would succeed only in destroying the "235," not in isolating it

The only other difference between uranium-235 and 238 that is of any consequence is a very, very slight difference in weight U-235 is lighter The scientists seized upon this slight difference in weight as the only hope for devising an effective method of separation Several possible approaches were followed One of the first was a process known as electromagnetic separation This consisted of combining the uranium with another substance to form a gas, then charging the gas electrically, then shooting it in a stream of molecules past a giant magnet The theory was that the lighter molecules would be deflected ever so slightly more than the heavier ones as they passed the magnet, and thus could be collected separately

Fantastic as it may sound, this process actually worked, and a $350,000,000 plant was erected at Oak Ridge to carry it out It is a matter of considerable interest that this plant actually produced the uranium-235 that was used in the first atomic bomb that exploded over Hiroshima in August 1945 This process, however, has since been abandoned, for the very good reason that another process was developed about the same time that turned out to be better and more efficient so far as the production of uranium-235 in relatively large quantities is concerned

It is this newer process, called "gaseous diffusion," that is still used today in the great plants now built or build-

ing at Oak Ridge, Paducah, and Portsmouth, in which the government has invested slightly more than three billion dollars So far as its basic principle is concerned, the gaseous-diffusion process is not a complicated one If you know how a sieve works, you know how gaseous diffusion works, for the basic idea is essentially the same Uranium in gaseous form is simply pumped through a series of "sieves," called barriers, and the lighter atoms of U-235 are gradually concentrated and taken off at the end of the line in virtually pure form It is not nearly so simple as separating sand from gravel, however, for in the gaseous-diffusion process we are dealing with individual molecules of matter so small that they cannot be seen even with the most powerful microscope It is these molecules that must be sifted through the barriers, and therefore the holes in the barrier material must be unbelievably small—less than one two-millionth of an inch in diameter Another complicating factor is that the difference in weight, and therefore in mass, between the molecules of the heavier U-238 and the lighter U-235 is less than one per cent This means that if you sent your mixture through but one barrier, the increase in the proportion of U-235 present would be so small that it could hardly be measured The mixture therefore must be sent, not through one barrier, but through thousands, and this is why gaseous-diffusion plants are so large

It is hard to imagine uranium, one of the heaviest metals in the world, in the form of a gas Yet it must be made into a gas if it is to be separated, and so, as the first step in the gaseous-diffusion process, the chemist—the "indispensable man" of the atomic energy program—is called upon to put it in gaseous form

It is rather typical of the perversity of nature in matters of this sort that the only gas that can be used in the gaseous-diffusion process is uranium hexafluoride, which is composed of one part of uranium to each six parts of

our old corrosive friend, fluorine. To make "hex," as uranium hexafluoride has come to be known throughout the atomic energy program, the chemist turns to the green salt we left at Fernald when we decided to follow the plutonium route to a bomb.

Green salt, like "hex," is composed of uranium and fluorine, but it contains proportionately more uranium than does "hex." The chemist's problem, then, is to introduce more fluorine into the compound he already has. This job entails all of the difficulties and potential hazards that anyone who handles fluorine must face, and these are compounded by the unpleasant fact that the chemical bonding of the fluorine to the uranium must take place at a high temperature. But the chemist does it just the same, and the product he gets is now ready for the gaseous diffusion plant.

Let us look for a moment at this product. In making his "hex" the chemist has not only succeeded in producing a material that can be used in the gaseous-diffusion process, he has also produced a material that is nearly as corrosive and as dangerous to handle as either pure fluorine or hydrofluoric acid. Whereas green salt is a relatively docile compound, this is certainly not true of "hex." It will, like pure fluorine, severely corrode and sometimes ignite many metals and all organic materials if it touches them in the presence of air. And yet this is the material that must be fed into the gaseous-diffusion plants at Oak Ridge, Paducah, and Portsmouth. Moreover, the "hex" *must be used in the form of a gas, and yet at room temperature* it is actually a solid. To make it into a gas, therefore, its temperature must be raised. This means that while it is in the gaseous-diffusion plant it must be kept relatively hot, a condition which adds to its corrosiveness.

It should be clear from this that a gaseous-diffusion plant must incorporate some design features and some materials that are not required in the usual industrial

plant For one thing, the whole system must be leak-proof, for another, nothing in it must be made out of anything that reacts with fluorine—and that includes most common materials This latter requirement naturally presented some rather difficult problems to the designers of the gaseous-diffusion process, particularly when it came to such things as lubricants and seals—articles that are generally made out of the organic compounds that fluorine likes best

The way in which these problems were solved comprises one of the most interesting stories in the entire atomic energy program Briefly, it consisted of an all-out research effort to find, or to develop if need be, a group of plastics, oils, and waxes that would be immune to the intense corrosiveness of uranium hexafluoride Now if there is anything in the world that is immune to fluorine it is quite obviously fluorine itself It is not surprising, therefore, that this research effort led to the development of a whole series of brand-new materials in which fluorine is one of the main constituents

These raw materials—called fluorocarbons, because they are combinations of fluorine and carbon—are colorless, odorless, harmless, and chemically stable One of the most appealing things about them is that they are not only resistant to fluorine, but are also resistant to practically everything else, including heat, fire, water, most acids, and—oxygen, the culprit in the atmosphere that causes the fairly rapid deterioration of so many similar substances

Here is a case, then, where the atomic energy program has produced, as a by-product, a new series of materials that will inevitably find many important applications in the manufacture of such things as tough, long-wearing plastics, oils, and possibly paints I know this is a prediction, but it is based on the knowledge that at least one new, valuable use for fluorocarbons has already been

found—in the production of plastics for protecting costly metal products from corrosion and for insulating electronic equipment Fluorocarbons are expensive now, and this limits the range of their application, but the price is bound to come down as production is increased to meet the demand that new uses will create

Now that your uranium, in the form of "hex," is ready for its journey through one of the Atomic Energy Commission's three gaseous-diffusion plants, it is placed in a metal container, specially constructed for safety purposes, and sent, let us say, to Oak Ridge, where the first gaseous-diffusion plant ever built is still in operation It is operated for the Commission by the Union Carbide and Carbon Company

Oak Ridge is a busy town of about 35,000 people, nestled in a long, narrow valley stretching between two moderately high, wooded ridges in the hills of eastern Tennessee, about twenty miles west of Knoxville To accommodate itself to its valley home, the town is about nine miles long and only about a mile or so wide at its center

If any town in the United States has the right to be called "Atom City," it is Oak Ridge It is the oldest of the communities built to house atomic energy workers, and it is the largest and most diversified It is the home not only of the gaseous diffusion plants, but also of the Oak Ridge National Laboratory, where a great variety of research work is performed, and the Oak Ridge Institute of Nuclear Studies, which, in co operation with a group of southern universities, is a major training center for the atomic energy program

Oak Ridge was built during the war by the Army Corps of Engineers At the height of the construction period more than eighty thousand people were crowded into the temporary dormitories and homes that had been literally

carved out of the wilderness Those were days of bustle and bulldozers, mud, and movement, and from it all there arose the first gaseous-diffusion plant, the pilot plant for the reactors at Hanford, the first and only electromagnetic-separation plant, and the Oak Ridge National Laboratory

Of these, only the electromagnetic-separation plant has been shut down, and this, as we have seen, only because the gaseous-diffusion method turned out to be very much better But the buildings of the electromagnetic plant are still used to house a variety of miscellaneous activities, mostly having to do with research

The town of Oak Ridge still retains many of the outward features of a typical Army post—roominess, low-lying frame buildings, and here and there a barracks-like dormitory Many of the commercial, residential, and office buildings are temporary structures left over from the early Manhattan District days But the face of Oak Ridge is changing As the temporary buildings outlive their usefulness and are removed, permanent stores, schools, and homes go up in their place Oak Ridge is beginning to take on the look of a typical American community, particularly in the residential areas which climb the wooded ridge behind the center of town

Like Richland in Washington, Oak Ridge is an open city Visitors may drive into it, shop in its stores, visit its homes, and browse through its principal public showplace, the American Museum of Atomic Energy But the plants and laboratories, which lie in three widely separated valleys away from the town, are out of bounds to the average visitor

It is out into one of these valleys, past the sign that reads Prohibited Area," that your uranium now must go, there to begin its long, tortuous journey through the gaseous-diffusion plant

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diameter. But these are the lengths to which man must go to isolate the explosives—and the fuel—of the atomic age.

When your pound of uranium, in the form of "hex," arrives at Oak Ridge, it is into this remarkable system that it is placed. It goes into one of the many compartments as a hot gas, and from there it is cycled and recycled through thousands of other compartments and past thousands of barriers until part of it can be drawn off as gas containing virtually pure uranium-235.

This is the way it works. When your "hex" has been inserted into the plant, and after about half of it has passed through the first barrier into the next forward compartment, the remaining half—slightly depleted in "235"—is drawn off and sent backward to a compartment at a lower stage in the chain. This must be done by halves, because if all or too much of the gas in the first compartment were permitted to pass forward to the next stage, the proportion of "235" in the succeeding stage would not increase. The whole purpose of the plant, of course, is to increase that proportion bit by bit.

This backward-forward movement is repeated at each of the thousands of stages in the plant, with each molecule of the "235" gas inching its way gradually forward through the plant, and each molecule of "238" gradually inching its way backward. The net forward movement is so slight that it takes even the "speediest" molecule many months to pass through the entire plant, and the volume of gas at the lowest stage is more than 100,000 times greater than it is at the uppermost, where the uranium-235 "cream" is taken off.

Once out of the plant, the "hex" that is now highly enriched by uranium-235 goes again to the indispensable chemist, who removes the fluorine, leaving, finally, pure uranium-235 metal. This metal looks exactly like normal natural uranium, and, as a matter of fact, it *is* exactly like

If you have never seen a gaseous-diffusion plant, there are no words that will prepare you for such an experience Your first impression, as you view it from afar, is one of sheer size The plant at Oak Ridge is the largest continuous-process plant in the world Its main building, in the form of a giant "U" three stories high, covers an area a half-mile long and a quarter of a mile wide Nearby are three very large, but somewhat smaller, buildings, with another one under construction At the time this is written, the floor area of the buildings already in operation is equivalent to more than sixteen city blocks

But if the impression you receive from afar is one of sheer size, the impression a close-up view gives you is one of sheer complexity If you were to walk into one of the many doors of the main building—doors large enough for a heavy truck to drive through—you would find around you almost a solid maze of pipes, wires, and instruments It is impossible to describe the intricacy of this equipment, but it is possible to convey a feeling for its bulk For instance, just for the two most recent additions to the plant, not including the main original building, the copper tubing and other pipe material required would extend in a line from Washington, D C, to Hartford, Conn, enough electrical wiring was used to stretch a telephone cable from Jacksonville, Fla, to Boston, and the building siding needed would enclose nearly two hundred six-room houses

To operate its thousands of pumps, the Oak Ridge diffusion plant, like its sisters at Portsmouth and Paducah, uses as much electric power each day as New York City, and to control the temperature of the hot 'hex' gas the plant uses more water daily than the city of Washington

This, as you can see, is a big operation, and yet all of it is set up for just one purpose—to push a gas, a molecule at a time, through a series of barriers perforated with minuscule holes smaller than two millionths of an inch in

CHAPTER *iv*

The Expanding Program

Most people, I feel sure, have no idea how much the atomic energy program has grown in the six years that have passed since the civilian Commission took over from the Army's Manhattan Engineer District. At the big production centers at Oak Ridge and Hanford, originally built during the war, three major expansions have been undertaken. In addition, three more entirely new billion-dollar production plants have been established at Aiken, South Carolina (called the Savannah River plant), Paducah, Kentucky, and Portsmouth, Ohio.

Each of these important expansions has called for new facilities all along the ore-to-weapons chain—at places like Los Alamos and Sandia, established during the war, Fernald, Ohio, where a new feed-materials processing center has been erected, and Eniwetok and Las Vegas, where new weapons-testing ranges have been set up. Add to these the new research and development facilities at such older locations as Oak Ridge, Brookhaven, Argonne, Berkeley, and Schenectady, and such new locations as Miamisburg, Ohio, the reactor testing station in Idaho, and the atomic power laboratory at Pittsburgh, and you will begin to appreciate the scope and rapidity of the atomic energy program's growth.

normal natural uranium—except for two interesting differences it is ever so slightly lighter, and it will, if brought together into a "critical mass," explode like an atomic bomb

As with plutonium, the amount of uranium-235 that has emerged from your original ton of ore is but a fraction of an ounce And also, as with plutonium, this product goes from Oak Ridge deep behind the cloak of secrecy to the places where it is machined and finally stored in atomic bombs

You will recall that plutonium deteriorates so slowly that only half of it is gone in 24,000 years In this respect, uranium-235 is even better, for only half of it will be gone in 710 million years Like plutonium, then, it is, so far as we are concerned, a stable, permanent material of immense value, for it can be used not only as an explosive in weapons, but also—if it need never be used in weapons—as fuel for atomic power plants It is therefore, like plutonium, a national resource of very great importance—a guardian of our freedom today, and a real hope for the future

5 The materials required to build the Savannah River plant would fill a string of railway cars stretching all the way from New York to St Louis

6 The labor force currently engaged in atomic energy construction comprises more than 65,000 people, or about five per cent of the total construction force of the nation

As can be seen, the Commission is engaged in an enormous construction operation, and the problems associated with it are commensurately large To provide an idea of the scope and variety of these problems, here is a list of the steps that must be taken as the Commission moves into a major expansion program of the type that is now underway

1 *Determination of the need*

The most recent expansion program will ultimately cost over $4,000,000,000 Obviously this is not the sort of undertaking that can be entered into lightly or without thorough study based on hard facts

The idea that an expansion program is needed may originate from any one of several different reasons Russian progress, an increase in the availability of uranium, or a new scientific development promising new military uses for atomic energy But whichever single factor motivates the expansion, all are taken into account before construction work is actually begun, and the final decision invariably involves a good many agencies of government besides the AEC The Defense and State departments, the Office of Defense Mobilization, the National Security Council, the Bureau of the Budget, the President, and the Congress, all participate in these important national policy decisions

2 *Determination of the size*

Here is a typical example of how the size of a major expansion is determined Commission research produces the likelihood that a variety of new weapons can be developed This is reported to the Department of Defense,

Because of security restrictions, it is very hard to describe this growth in detail, particularly as it relates to the nation's capacity to produce weapons materials, but a good idea can be obtained by comparing today's $5,000,000,000 capital investment in atomic energy with the $1,400,000,000 that applied in 1947 When the current *construction program is completed, the figure will have* climbed to about $9,000,000,000, which well exceeds the combined capital investment of General Motors, U S Steel, du Pont, Bethlehem Steel, Alcoa, and Goodyear It is also interesting to compare these figures with the $366,000,000 cost of the Panama Canal—a project which took ten years to complete Even taking the devaluation of the dollar into account, the cost of the atomic energy building program over the past six years is about ten times that amount

Here are some other illustrations of the magnitude of the current construction program

1 The new plant at Portsmouth will have a gross floor area equaling that of the Pentagon Building and the famed Willow Run bomber plant combined

2 The concrete required by the Savannah River plant at Aiken is sufficient to lay a sidewalk five feet wide and six inches thick from coast to coast, and the excavation work will turn up enough earth to form a wall ten feet high and six feet wide from Los Angeles to Boston

3 The three uranium-235 production plants at Oak Ridge, Portsmouth, and Paducah, when completed, will consume more electric power each day than is produced by the Hoover, Grand Coulee, and Bonneville dams plus the entire original TVA system combined—or more than four times the average daily amount used by New York City in 1952

4 Four times as much structural steel is being used in the Paducah plant as was used in the Chrysler Building in New York

After the NSC's Atomic Energy Committee has reviewed the expansion plan, it goes to the full Council for approval The Council consists of the President, the Vice President, the Secretary of State, the Secretary of Defense, together with such other high officials as the President may name to it In its deliberations on atomic energy expansion matters, the Council usually hears reports from the Chairman of the AEC, the Director of the Office of Defense Mobilization, and the members of the Joint Chiefs of Staff After the Council approves the expansion plan, it goes to the President for his final approval If he in turn approves it, the important job of explaining the need for the expansion to the Congress begins

4 *Securing Congressional approval*

This involves, first of all, working closely with the Budget Bureau to determine the exact dollar amounts that will be needed to get the program under way Once this is done, the President sends his request for these funds to the House of Representatives, and the Commission prepares to go before the Appropriations Committee of the House to justify the request During these hearings, which frequently run for several days, the Committee looks into the over-all need for the expansion and examines the individual budget items included in it

The House can do one of several things to a budget request It can deny it, approve it, or cut it It usually cuts it, frequently by ten to fifteen per cent, and sometimes more, apparently on the theory that the Commission is asking for something it really needs, but that it is probably asking for more money than is necessary to accomplish it Curiously enough, for reasons I will describe in the next chapter the Commission frequently asks for too little

If the Congress, for good reasons, makes cuts on specific items in the budget, the Commission can understand that and can discuss intelligently with the appropriate com-

which then evaluates its need for these new weapons in the light of its current war plans, the international situation, and the rate of progress, as we know it, of the Russians

While this Defense Department evaluation is under way, the Commission looks into the technical and economic feasibility of expanding the program and roughly *establishes the upper limits that it believes can be accomplished* This involves an exhaustive study of the foreseeable uranium ore supply and an intensive investigation—with the Office of Defense Mobilization—of the availability of key materials and man power in relation to other defense needs The Defense Department then presents a statement concerning the additional weapons required, and the Commission states whether or not in its judgment this goal is technically and economically feasible The size of the proposed expansion, therefore, is determined jointly by the Atomic Energy Commission and the Department of Defense Throughout the development of these plans, which generally takes several months, the Commission's General Advisory Committee and the Joint Congressional Committee on Atomic Energy are kept fully informed, and their views are given great weight

3 *Proving the need*

The undertaking of a major expansion is clearly an important step in the development of the nation's over-all security plans Once the Commission and the Department of Defense agree jointly on an expansion goal, therefore, the whole idea is reviewed by the Atomic Energy Committee of the National Security Council in order to determine whether it conforms with broad national policy In addition to the Chairman of the AEC and the Secretary of Defense, this committee also includes the Secretary of State, thus assuring that the expansion coincides with our foreign policy objectives and with the State Department's current estimate of the international situation

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mittees the precise effect these cuts will have But across-the-board cuts of a fixed percentage are hard to understand, hard to live with, and hard to rebut with specific data Yet, too frequently this is the kind of a cut that is made

After the House has acted on the budget request, it goes to the Senate, where more hearings are held before the Senate Appropriations Committee If there is a difference between the appropriations bills as finally passed by the House and Senate, as there frequently is, this difference is resolved by a Joint Conference Committee Then the appropriations bill, representing Congressional authorization for the expansion, is passed by both Houses of Congress and sent to the President for approval If he signs it, then, and not until then, is the Commission in business

I think it is pertinent to note what happened to the last big expansion program the Commission took to the Congress—the one currently under way and which involves the new plant at Portsmouth, among other important new construction The Congress approved that program, but by the very narrowest of margins To enter into the necessary contracts and get it started, we needed roughly $3,000,000,000 the first year We consequently asked for that amount, and we asked for it at a bad time—just before the political conventions in Chicago last summer and toward the end of the Congressional session We would have preferred to wait for quieter times, but the urgency of the expansion was such that we felt the nation could not afford to wait

When we presented our case to the House Appropriations Committee, this is what I said

"We are well aware that this is no ordinary request for funds

"We know that it involves a very large sum of money—

the largest single sum ever requested for the national atomic energy program

"We know, too, that it involves a very large construction effort that will inevitably make heavy demands upon many critical materials that are in short supply

"And we know that it comes at a time when other defense expenditures are extremely high

"And yet we have concluded that this request must be made As a matter of fact, we strongly believe—on the basis of all the information we have had—that we would be grossly derelict in the discharge of our responsibility if we failed to make it, and if we failed to make it at this time

"The setting in which this request is made stems from recent revolutionary developments in the field of atomic weapons technology Through these developments, the whole concept of how atomic weapons can be utilized in warfare has been radically revised

'No longer are they looked upon only as devices to be used in an Hiroshima-type' way against cities and industrial areas It is now possible to have a complete 'family' of atomic weapons, for use not only by strategic bombers, but also by ground-support aircraft, armies and navies

"The Department of Defense is very much aware of this change in concept, and atomic weapons are being incorporated into the operational plans of all three of the armed services

'This, quite naturally, has greatly increased the demand for atomic weapons—to an entirely different order of magnitude than obtained a few years ago

'It is the purpose of this expansion to meet this new demand and to meet it as soon as possible

We could, of course, meet this demand eventually with the facilities we now have on hand or building But we would meet it much later This new expansion is designed

mittees the precise effect these cuts will have But across-the-board cuts of a fixed percentage are hard to understand, hard to live with, and hard to rebut with specific data Yet, too frequently this is the kind of a cut that is made

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This the Senate, after a historic and dramatic debate lasting over the Fourth of July week end, rejected by the very narrowest of margins The vote was actually a tie—34 to 34—which meant that the report was not adopted

The Conference Committee went back to work, and, after a series of compromises, we finally ended with the rider after all—but with $2,898,000,000 instead of the $1,450,000,000 we had originally been given This was the minimum amount we needed to get the program started as long as the rider remained in force, and we began putting it to good use as soon the President signed the appropriations bill

Thus the Congress, while refusing to give up on the principle of the rider, nevertheless gave us the money we needed to overcome its restrictive effect It was a curious result to a stirring, nonpartisan legislative battle, and one that I would never have predicted in advance But we were satisfied with the result because we were given what we needed I can't say, however, that the train of events leading to this result did anything to add to our equanimity

5 *Decision on whether to build a new site*

Very early in the development of plans for a new expansion the Commission must decide whether it would be best to enlarge existing plants or to build new ones Normally, one would think, it would be cheaper and simpler to enlarge existing facilities than to establish new locations But this is not always the wisest and most practical thing to do, and there may be any number of reasons why this is the case

One of these reasons involves power Gaseous-diffusion plants, such as those at Oak Ridge, Paducah, and Portsmouth, use tremendous quantities of electric power Usually, to meet this demand, new power plants must be erected in the same utility region as the Commission's plant But it turns out that you can build a gaseous-diffu-

to reach the minimum military stockpile requirement at least four, and possibly five, years earlier than would otherwise be the case—four years in which we can be sure the Soviet Union will not be idle"

The House, after debating the need for this expansion and agreeing that it was necessary, then proceeded to cut the appropriations request severely—back to $1,450,000,000, or about half the amount we had determined we would need for the first year Furthermore, the House inserted a rider which said that we could not start any construction project for which we did not have the money we would need to complete it This meant we could start only part of the program In fact, *it meant we could start only* a very small fraction of it, because the whole program was so highly integrated that it either had to be started *in toto* or not at all We could, of course, have taken our $1,450,000,000 and gone back and devised an entirely new expansion program costing that amount (which would have taken months more to work out), but it would have been a different kind of program, and it would not have reached the weapons goals by anywhere near the date the President, the National Security Council, the Department of Defense, and the Commission had determined to be necessary

We therefore went to the Senate and explained our reasoning We told the Senate Committee that we could get along with the heavy reduction in dollars if we could only have relief from the restrictive rider We figured that if we could use the $1,450,000,000 to begin projects we could pay for with money to be obtained later, we could get under way The President also sent a strong letter to the Senate asking for the same relief The Senate agreed with us and instructed its members on the Joint Conference Committee to try to eliminate the rider

But the House remained adamant, and the Conference Committee sent back a report with the rider still in it

to deteriorate When one of our existing installations approaches this size, therefore, we begin to think in terms of a new location when an expansion becomes necessary In addition, if we are planning to build a new plant that may someday have to be enlarged still further, we may decide that it would be prudent to put it in a new location at the outset

6 *Decision on whether to build a new government town*

It usually hasn't taken the Commission very long to dispose of this problem The answer is invariably "no," and it is generally arrived at by common agreement almost before it is raised The Commission has established no towns since it took over the atomic energy program The three "atomic towns' now owned by the Commission—Oak Ridge, Richland (where the Hanford plant is located), and Los Alamos—were all built by the Manhattan Engineer District during the war We inherited them, but we would be much happier if we hadn't, and we are trying to dispose of Oak Ridge and Richland to private ownership right now

One of the main troubles with being in the town business is that city management and atomic energy are two entirely unrelated sciences Although the Atomic Energy Commission prides itself on knowing how to run an atomic energy program, it will freely confess that it is not expert in running cities It turns out, however, that practically everyone with whom the Commission deals fancies himself as an expert on town management To say that the AEC has a critic or two in this area would be to put it mildly

The Commission simply does the best it can It hires the best community management people it can obtain for the salaries it is able to pay, it receives the best outside advice that is available through the medium of advisory panels, and it uses contractor-employed professional city manage-

sion plant slightly faster than you can build a power plant This means that the Commission makes very heavy temporary power demands upon existing power facilities in the area where it is building Frequently an area where the Commission already has a large plant cannot meet this interim power demand, and this makes it necessary to go to another part of the country In addition, the Commission has tried to be careful about developing the power resources of any single region beyond the point where the power can be absorbed if for one reason or another the atomic energy program ever goes out of business If the Commission has reached this point in one region, therefore, it has felt that it should move on to another when a big new expansion came along

Another reason involves vulnerability As a general rule, the Commission has felt it would be highly unwise to put all of its production eggs in one or two over-sized baskets that could easily be knocked out in time of war It wants more than one production line moving from the ore fields to the bomb stockpiles In this way it can keep any single target from becoming uniquely attractive, and thus have a better chance of keeping the production line flowing in case of atomic attack

There are other important factors to be taken into account in deciding whether a new site is necessary If the expansion, for example, involves building a new plant incorporating an entirely new process, with new and different types of supporting facilities, as the Savannah River plant entails, then the plant is built at a new site Also, if there is a good deal of construction work already under way at an established site which any new work would interfere with, then serious consideration is given to going elsewhere

Another important reason involves efficiency The Commission has felt that there is an optimum size to an atomic energy facility beyond which management efficiency tends

erning, privately owned communities The panel recommended that Los Alamos, home of the Commission's main weapons laboratory, remain for the time being under government control and ownership because of security considerations

As a result of this report, the Commission has, during the past several months, taken a series of specific steps leading to the relinquishment of government control over Oak Ridge and Richland The homes and business buildings have been appraised, and recommendations for required changes in the law have been developed

Beyond its strong desire to get out of the town business, the Commission's main concern in all this is that the change-over be handled in such a way that no damage to the atomic energy program results from it In other words, the Commission wants these communities to remain as attractive and pleasant places in which to live, so that the recruitment and retention of workers will not suffer This means that the usual municipal services must be of high quality, that the school system must be good, and that the tax rates and living costs must be comparable to those of similar communities in other parts of the country

With these conditions in mind, the plans for incorporation of Oak Ridge and Richland are going forward, and their reconstitution as private communities will probably take place in the near future if the necessary legislation is obtained Even after this has happened, however, a government subsidy of some sort will probably be necessary for some time, because there are no private industries in Oak Ridge and Richland upon which to build a realistic tax base

While the Commission's plans for disposal are going forward, it is trying steadily to improve its management of these towns so that they may be ready for incorporation when the time comes and government subsidy can be held to a minimum To this end, the Commission has in the past

ment people to carry out the day-to-day operations, such as the maintenance of homes and buildings and the collection of rents

But the demands the Commission's town responsibilities make on the time and attention of its key officials and their staffs are still far out of proportion to their relative place in the total program As just one example, the Budget Office at Oak Ridge has told me that it devotes about thirty per cent of its time to community matters, although, in fact, the town of Oak Ridge consumes only about seven per cent of the budget In all, out of the 22,000 people gainfully employed at Oak Ridge by either the AEC or its contractors, about 2,200 are engaged in town functions of one sort or another

The Commission strongly believes that the idea of government towns is alien to the principles of American democracy Although it tries to make its towns as normal as possible, this simply cannot be done where the government is both landlord and mayor It is hard, under these conditions, for even the most civic-minded citizens to develop a real sense of responsibility toward their community They pay no local taxes—only rent And they can't vote for the officials who actually run their local municipal affairs In other words, they cannot enjoy the full rights of American citizenship It isn't normal and it isn't good

The AEC's objective, then, is to avoid establishing any new towns and to get out of the town business entirely as soon as possible To this end, in the summer of 1950, we appointed a special panel of community experts to study the problems of transferring our towns to private ownership and self-government The panel was headed by Richardson G Scurry of Dallas, Texas, a nationally known expert in the town management field Mr Scurry's panel, after about a year's study, reported that in its opinion the Commission should dispose, in an orderly way, of Richland and Oak Ridge so that they might become self-gov-

erning, privately owned communities The panel recommended that Los Alamos, home of the Commission's main weapons laboratory, remain for the time being under government control and ownership because of security considerations

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ment people to carry out the day-to-day operations, such as the maintenance of homes and buildings and the collection of rents

But the demands the Commission's town responsibilities make on the time and attention of its key officials and their staffs are still far out of proportion to their relative place in the total program As just one example, the Budget Office at Oak Ridge has told me that it devotes about thirty per cent of its time to community matters, although, in fact, the town of Oak Ridge consumes only about seven per cent of the budget In all, out of the 22,000 people gainfully employed at Oak Ridge by either the AEC or its contractors, about 2,200 are engaged in town functions of one sort or another

The Commission strongly believes that the idea of government towns is alien to the principles of American democracy Although it tries to make its towns as normal as possible, this simply cannot be done where the government is both landlord and mayor It is hard, under these conditions, for even the most civic-minded citizens to develop a real sense of responsibility toward their community They pay no local taxes—only rent And they can't vote for the officials who actually run their local municipal affairs In other words, they cannot enjoy the full rights of American citizenship It isn't normal and it isn't good

The AEC s objective, then, is to avoid establishing any new towns and to get out of the town business entirely as soon as possible To this end, in the summer of 1950, we appointed a special panel of community experts to study the problems of transferring our towns to private ownership and self-government The panel was headed by Richardson G Scurry of Dallas, Texas, a nationally known expert in the town management field Mr Scurry's panel, after about a year's study, reported that in its opinion the Commission should dispose, in an orderly way, of Richland and Oak Ridge so that they might become self-gov-

energy plants This is a matter the Atomic Energy Commission itself will have to settle

I hope you will place these plants where they will be most useful for the objective you are trying to obtain and that you will allow no pressure groups of any sort to influence you in their location

/s/ HST

Although I hope it is needless to say so, I would like to emphasize that the Commission has never allowed any outside pressures of any sort to influence it in the selection of a location for a new plant, with one possible exception It has taken into consideration, and I think necessarily and legitimately so, the over-all attitude of the residents in the various areas it has had under consideration for certain plants If this local attitude has been unanimously, or nearly unanimously, against location of the plant in that area, and if the reasons put forward are good ones, the Commission has taken this fact into account in its deliberations—but even then only if all other factors are equal It attaches some importance to this local attitude, however, because it can see that a generally unfriendly reaction could easily cause delays, headaches, and added expense that might adversely affect the total program later on

But there are so many other technical and administrative factors affecting the location of a new plant that the Commission would soon find itself with some rather horrible mistakes on its hands if it for a moment permitted selfish outside interests to influence its final selection decision Here are some of the principal factors which *do* govern the selection of new sites

1 *Vulnerability*

According to military authorities, some sections of the country are more vulnerable to foreign attack than others The Commission therefore tries to locate its facilities in the least vulnerable areas Also, within this preferred

ever, in every case the news must become public, and then begins the deluge of contacts from people who either want the new plant very badly or who just as strongly hope we will locate it somewhere else These people approach the President, the Congress, and the Commission

During our effort to find a suitable location for the plant ultimately located at Portsmouth, we received more than seven hundred letters from Chambers of Commerce, public officials, labor organizations, and individuals, and a score of personal visits by delegations from various cities These were divided about equally between those who wanted the plant and those who didn't Most of the people who wanted the plant wanted it because they needed new industry, and consequently new employment and business opportunities in their area Most of the others were opposed to the plant because of an already tight labor situation, because they thought it would increase their attractiveness as a bomb target, because of a housing shortage, or because the plant would be located in a region attractive as a farming or residential area Portsmouth, Ohio, where the plant was finally located, wanted it very badly No one kept a record of the number of phone calls we received about the location of this plant, but I am sure they exceeded the number of letters and personal visits

When we were looking for a site for the Savannah River plant we received well over six hundred letters or personal visits, mostly from people wanting the plant How many the Congress and the President received, I don't know, but I do know that President Truman must have received a good many, for at the height of the interest in the plant location problem, on August 19, 1950, he sent me the following note

TO THE CHAIRMAN, ATOMIC ENERGY COMMISSION

I've had delegations from Arkansas, Missouri and several other States in regard to new locations for atomic

5 *Accessibility*

The site, to be useful, should be convenient to transportation systems, such as railroads, highways, rivers, and airlines

6 *Labor*

When you set out to build a plant requiring 30,000 to 40,000 construction workers and 5,000 to 10,000 permanent employees, the labor supply in the various areas under consideration becomes very important The total labor demand hardly ever can be met locally, but the Commission always tries to recruit as many workers as it can locally, and it does not wish, in the process, to interfere with other essential defense work If a good deal of other defense work is located in an area, therefore, the Commission looks elsewhere

7 *Housing*

Since one of the Commission's objectives is to avoid the establishment of another government town, the proximity of the various sites under consideration to towns large enough to accommodate a substantial percentage of the work force is a very important factor This is why the Savannah River plant is near Augusta, Georgia, and Aiken, South Carolina, why the new Ohio plant is near Portsmouth and Chillicothe, and why the new Kentucky plant is near Paducah

8 *Climate*

The Commission always tries to select a site where valuable construction and production time will not be lost because of excessive heat, cold, rain, or snow, and where recruitment and retention of workers will not be adversely affected because of weather extremes

9 *Safety and Security*

Although one objective is to locate near cities providing adequate community facilities, the site must also be sufficiently isolated to make the maintenance of security possi-

zone, it is in the interest of national security to keep vital defense industries and facilities as widely dispersed as possible

2 *Power*

This is especially important in the selection of sites for gaseous-diffusion plants, which use fantastic amounts of electrical power As a result, these plants must be built in areas where the sources of power are plentiful and cheap Most of the power used in the AEC's gaseous-diffusion plants comes from coal, so you will find the plants invariably located in areas where coal is available in large quantities and at low cost Oak Ridge's power comes from TVA, Paducah's partly from TVA and partly from a private utility network in the Illinois-Missouri-Kentucky area, and Portsmouth's comes from a private utility network in the Ohio-West Virginia-Indiana area Power is not quite such a controlling item in the location of plutonium production plants, but it is still very important

3 *Water*

A large supply of fresh water is a controlling factor in the location of the production facilities (Hanford and Savannah River) which use nuclear reactors Both the plant at Hanford, located on the Columbia River, and the Savannah River plant in South Carolina use more water daily than a city of over a million people Adequate supplies of water are also important to the operation of gaseous-diffusion plants, which explains why Oak Ridge is on the Clinch River, Paducah is on the Ohio, and the Portsmouth plant is on the Scioto, just north of the Ohio

4 *Terrain*

Plants as large as the AEC's big production facilities require a terrain that is relatively level and free from such construction impediments as rocks, ravines, and an excessive amount of trees The area and its approaches must also be free from flooding

ciencies were uncovered in the on-the-spot surveys, this list was gradually reduced to 84, then 17, then 7, and finally 5, listed in order of preference

Just to make sure that the best possible technical opinion is being brought to bear upon the problem of site selection, the Commission, as the surveys progress, appoints a Site Review Committee to double-check the conclusions of the architect-engineer contractor This Committee is composed of leading experts drawn from the construction engineering professions They review all of the data in detail and may either endorse or revise the recommendations of the private contractor

The Commission also enlists the aid of many other agencies of government the Labor Department, to settle questions of potential labor supply, the Federal Housing Administration, to assist on matters relating to housing requirements, the Department of the Interior, to comment on power supply questions, the National Security Resources Board, to appraise the degree of industrial concentration, and the Department of Commerce and the Office of Defense Mobilization, to comment upon business impact

After all the data are in, the final decision as to which of the many sites should be selected is made by the five Commissioners in Washington Frequently questions arise which entail re-surveys and re-evaluations of the data already produced, and often Commission staff people are dispatched to the sites under final consideration to bring back firsthand word on specific details But the final responsibility rests with the Commissioners, and it is one that is discharged in the most meticulously fair manner that they can devise I know that each time we selected a site while I was on the Commission we greatly displeased a large number of people who had hoped to obtain it I know this, because these people *did not hesitate to tell us* so But I would like to say this Each of the new plants we

ble, and to protect the surrounding area from any unusual hazard Safety is a particularly important factor in plants utilizing reactors, such as Savannah River, where a site of 250,000 acres was required, largely for safety reasons

10 *Land Value*

When a new site is established, the Commission tries to avoid taking over land which has special value for agricultural, residential, or some other equally useful purpose It tries to stick to land of only marginal value at best Even if there were no other considerations involved, this would still be the AEC's policy because it does not want to invest any more money than necessary in real estate, and when you are buying a plot as big as 250,000 acres the purchase of land can be a very large item indeed

The process by which all of the possible locations for a new plant are sifted down to one is a formidable operation, and it involves a lot of people, both within and without the AEC It begins with a statement from the Department of Defense as to which are the preferred areas from a military defense point of view Then the AEC conducts a study to determine the general area or areas which appear to be most suitable from the standpoint of power and water supply An example of how this works is the Portsmouth plant, where it was decided very early that the plant would have to be located somewhere in the Ohio River Valley because of the availability of cheap power there After the general areas have been mapped out, the AEC with the Army Corps of Engineers takes a close look at all property already owned by the government to see whether some currently unused site might be utilized

At about this stage a private architect engineer firm is engaged to make on-the-spot surveys of the most promising territories and to make recommendations to the Commission as to which potential sites most nearly meet the complicated technical criteria For the Savannah River plant, 114 such locations were surveyed As various defi-

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undertook to build is located in the place which was best, in our considered judgment, from the standpoint of overall national interest, and I am convinced that a study of construction results to date will bear this out

11 *Selection of Contractors*

One might think that after the Commission had completed plans for an expansion, secured the approval of all interested parties, and selected a site for any new plants involved, it would be all set to go But this isn't quite true There are still a few more matters that require attention These include such important things as selecting the construction and operating contractors, entering into contracts for the very large amounts of power required, making arrangements for temporary housing for the influx of construction workers, arranging for roads to be built or improved, arranging for railroad lines to be extended into the site, and arranging for allocations of the strategic materials needed

All of these are vital to the success of the project, and all are time consuming But there is nothing more important than the job of selecting just the right construction and operating contractors Since the Commission performs virtually no construction or operating functions itself but confines itself to supervision, the selection of qualified contractors becomes one of its most important functions It is upon the success with which each of these contractors discharges his assigned responsibility that the entire success or failure of the program rests So contractors are selected with extreme care

The AEC contractor at the Savannah River plant is the du Pont Company In a departure from usual procedure, the Commission asked du Pont to perform all major phases of the work there They designed the plant, helped to select the site, are now constructing it, and will also be the operator Naturally they have the assistance of many subcontractors (over four hundred in all), but the prime con-

tract covers all major phases of the work. The selection of the du Pont Company for this job was not hard. Du Pont had designed, built, and operated the Hanford plant during the war, they were not engaged in any other atomic energy work at the time, and they possessed vast resources uniquely suited to the Savannah River operation. We were immensely pleased when they were persuaded to come back into the program.

But Savannah River is the exception. Usually the Commission has engaged an architect-engineer firm to do the design work, a construction company to do the construction, and an operating company to do the operating. At Paducah four architect-engineer firms were utilized, the F. H. McGraw Company is doing the construction, and the operating contract was awarded to the Union Carbide and Carbon Company, which also operates Oak Ridge. At Portsmouth we utilized eight architect-engineers, engaged Peter Kiewit and Sons to do the construction, and awarded the operating contract to the Goodyear Tire and Rubber Company.

The kinds of factors that are taken into account in the selection of major AEC contractors are: (1) ability to handle a job of the magnitude involved, (2) financial record and reputation, (3) experience and reputation in atomic energy or related fields, (4) ability and willingness to assign top management and key technical personnel to the AEC job, (5) past record in performing work for the AEC or other government agencies, (6) labor-relations record, (7) enthusiasm of top management toward the atomic energy job.

The procedure for the selection of contractors is somewhat similar to the site selection procedure, except that for obvious reasons no private firm is hired to make a preliminary survey. The initial studies are made by the AEC Operations Office under whose supervision the contract will fall. This Office circularizes all qualified companies,

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to bring in new companies not previously connected with the atomic energy field The purpose in this is to encourage as much competition as possible and to broaden the industrial base of the atomic energy program If atomic energy is ever to play a significant role in our economy, it is obvious, I feel, that as many industrial concerns as possible must be experienced in it The AEC therefore tries to use the current primarily military program as a device for educating American industry about atomic energy

Sometimes, however, because of the pressure of time and the great savings in costs that may result, the commission has had to turn to its existing contractors to carry on new work This is particularly true when an existing installation, such as Oak Ridge or Hanford, is enlarged It is also true at Paducah, where we turned to the Union Carbide and Carbon Company to be the operating contractor, even though they also were operators of the plant at Oak Ridge The reasons were that the Paducah operation is the same as the Oak Ridge one, and the need for the Paducah plant developed so rapidly that there wasn't time to go through a long selection procedure Both the construction contractor and the site were selected in this case in less than two months—because they had to be

I have described at some length the steps the Commission must go through to get an expansion under way because expansions have dominated the atomic energy program for the past several years, and because the decisions that have been made and the policies that have been followed have affected the lives and financial status of a great many people Some of these people have shown the Commission that they have had a hard time understanding why we chose some of the courses we followed I hope this chapter has thrown some light on how this expansion

sends representatives to talk with company officials, and invites company representatives to visit a similar AEC installation to learn about what the job would entail A contract board made up of key Commission technical people then reviews all of the information collected and makes recommendations to the General Manager and the Commission in Washington

The selection of the operating contractor at Portsmouth took a full year and involved the consideration of sixty different companies The selection of the construction contractor took seven months and involved the consideration of twenty-one different companies These selection processes, like the site selection one, had to begin many months prior to Congressional authorization of the expansion program Because of this preliminary work, the Portsmouth timetable was able to go like this The Congress approved the program in July 1952, the construction contractor was selected simultaneously, the site was selected in August, and the operating contractor was selected in September

As might be expected, a good many of the companies the Commission contacts are not interested in joining the program Frequently the reason is that they are too heavily committed to other work Interestingly enough, quite often the reason given is that the fee is too low One company, when we solicited a proposal, told us this "Frankly, we can see anything but a happy existence for a contractor in the performance of such a venture, through no fault of the AEC or the contractor either These cost-plus-fixed-fee jobs are open season for political investigators and newspapermen looking for someone to take a pot-shot at, and any desire to do a bang-up job would soon lose the enthusiasm, not only of the sponsor but his organization as well"

One of the general policies the Commission tries to follow consistently when it is looking for new contractors is

CHAPTER V

The Headaches

There are a good many headaches connected with an enterprise of the size and complexity of the United States atomic energy program, and a substantial share of them arise from the very large expansions described in the previous chapter Many of these construction jobs involve things that have never been done before, most of them involve secret processes and equipment, and all of them must be accomplished with the utmost speed Much of the difficulty comes from the great need for speed, which demands that engineering design follow right on the heels of research progress and construction right on the heels of engineering design

It is not like building a house When you want to build a house you can go to an architect and ask him to draw up the design your builder will follow If he is a good architect he knows the basic principles of house design and has the latest information None of the information is secret, it is all available in textbooks and trade journals So all you have to do is tell your architect what kind of house you want You may suggest a few features you are particularly interested in, and he may suggest a few you don't know about If you have trouble visualizing your house, he can have a model made to show you exactly what it will look

business has been handled and what has motivated the Commission Briefly, it has been the national interest, and that alone

As to the future, it is my opinion that this country is now engaged—or should be engaged—on the last major expansion of the productive capacity of the atomic energy program I say this because, after the current expansions are completed and the new plants have been in operation for several years, we will, figuratively, have atomic bomb material running out of our ears—enough, I would say, to meet any reasonable goal within a reasonable time that the military might establish This doesn't mean that from time to time it might not be desirable to enlarge a laboratory or a plant, or establish a relatively small new one, particularly in the field of reactor development, but the gigantic, multibillion-dollar expansions of the sort we have had in the recent past are, to my way of thinking, ended

pleted it will represent the very latest and best design that can be produced

By doing this, however, the Commission necessarily creates some headaches it would like very much to avoid For one thing, it frequently finds that it cannot enjoy the many advantages of open competitive bidding on its large and intricate construction jobs It is unreasonable, when you want construction work to begin before design work is completed, to expect the builder to set a firm price under which he will do the job It is not only unreasonable to ask for bids under these conditions, it would also be useless, for no responsible builder could bid And even if he could, neither he nor the government would have any idea how many contract modifications would have to be made later on to take care of the design improvements that might have to be incorporated

On nearly all other construction, however (such as roads, warehouses, sewerage, and office buildings), where time and the nature of the work will permit, the Commission follows the procedure of inviting bids and making awards to the lowest responsible bidder It is a source of considerable satisfaction to me that the Commission has gradually widened the area in which competitive bids are let as more and more of the construction work has become "conventional," and as a background of basic design data has been built up

But the prime contracts on the big, difficult, and pioneering construction jobs still cannot be awarded in this way, and the Commission therefore has relied upon a type of contract known as the CPFF, which means "cost plus a fixed fee' Under this type, the government, in effect, "hires' a company to do a specific job The Commission selects the contractor, it tells him what job it wants done, it pays all of his expenses, and in addition it pays him a fixed fee The fee is to compensate the company, at least in part, for the executive and other skilled talent that it

like After your house plans are complete it is a relatively simple procedure to shop them around among several good building contractors, receive estimates, and award your contract to the builder who gives you the best price

It is not quite so easy, however, where an atomic energy plant or laboratory is concerned In the first place, you can't go to just any good architect-engineer and expect him to know all there is to know in your field Atomic energy is too secret for that, and it is also too new Unlike houses, atomic energy has not been around very long, and in consequence few basic design principles have been established This means that the scientist who developed the basic idea of a new atomic energy plant or laboratory must frequently work alongside the people who are trying to reduce the idea to plans a builder can follow And usually there is not time to go through the intermediate step of building a model or pilot plant to see how the scaled-up process will work

Although it would be very nice to be able to wait until the designer had completed his work before letting the building contract—as one can do with a house—this is all too often impossible in the case of atomic energy This is true partly because of the great need for speed, and partly because of the great mass of original design work involved The blueprints for the Savannah River plant alone, for example, are equivalent to a strip of paper, one foot wide, stretching all the way from New York to Berlin

So, in most cases, the Atomic Energy Commission doesn't wait It doesn't wait long enough to build a pilot plant and it doesn't wait long enough for all the detailed design work to be completed It tries to keep construction as close behind the design as it can, in order not to lose precious months or years in the effort to build up our weapons stockpile And, I might add, the Commission tries to catch up with as many technological improvements as it can while the plant is building so that when it is com-

The Commission has tried to compensate for at least some of the inadequacies of the CPFF contract system by employing only companies with first-class reputations that would be damaged if they did not do a first-class, cost-conscious job The list of major operating and construction contractors to the Commission is a virtual blue book of American industry These concerns take a real pride in their atomic energy work, and they have a strong desire not to do anything that might hurt the fine reputations they have earned over the course of many years

One might think that there would be real enthusiasm on the part of industry for a type of contract by which the government assumed the whole risk and the contractor was paid a fee besides In actual practice, however, this is not the case No matter how much we might hear about the potential extravagance of the CPFF-type contract, there is no great desire on the part of industry to work under it The reason is that the fee, which is fixed in advance (it does not increase if costs go up), is simply not large enough to compensate most of our contractors for the resources they must assign to our work

Why, then, are they willing to work for the Commission under this kind of contract? From my own experience, I would say there are three principal reasons

1 *Sincere patriotism* the desire to do something to enhance the national security

2 *The ground-floor motivation* the desire to gain valuable know-how through experience that can be applied later on for profit when atomic energy may no longer be a government monopoly

3 *Prestige* the desire for the recognition that important pioneering work in a promising new industry can bring

These reasons, of course, affect each of the Commission's contractors in varying degree, but I am sure that one or the other of them is present in nearly every case In any event, it appears obvious that it is not the fee alone that

devotes to our work and that it might more gainfully utilize in some other way

There are a number of drawbacks to this method of doing business Not the least is the absence of a clear motive on the part of the contractor to cut costs and to do the job as cheaply as possible No matter how good a job he does, there is always the suspicion that he is not doing his best to hold costs down as long as the government is picking up the check This bothers the Congress, it bothers students of management techniques, and it bothers the Commission It also leads to all sorts of inquiries, investigations, and hearings, and it makes necessary the employment of Commission people to look over the shoulders of its contractors to make sure that cost-consciousness always plays a key role in their management operations

But, as yet, no one has come up with an equally good or better alternative so far as the big construction and operating contracts are concerned Competitive bidding is the obvious alternative, but this entails having final plans completed before the work begins, which is usually impossible, and it also involves going through a time-consuming bidding procedure before the contracts can be awarded In most cases, there simply is not time for all the paper work involved

Another alternative is for the government to do these jobs itself with government employees, and not look to industry at all But this also has its drawbacks For one thing, the government couldn't hope to hire all the top-flight talent it would need if it asked qualified people to leave industry to come with the program at government-level salaries, and, for another, the Commission has always felt that it is part of its mission, under the law, to indoctrinate American industry in atomic energy work so that industry can help speed the peaceful development of this new science One of the best ways to accomplish this objective is to invite industry to do the actual work

mate errors a design engineer makes are usually on the under side The law of averages would suggest that over a long period of time the errors would tend to equalize, so that eventually total costs would figure out about as anticipated But this isn't the case Even allowing for the inflationary factor which has been at work in recent years, estimates of costs too frequently come out too low I suppose the real reason is the human element—the tendency always to be just a trifle optimistic If you have ever tried to plan a household budget in advance, or to allocate a fixed amount to a vacation trip, I think you will understand what the Commission is up against And when the Commission succeeds in overcoming this tendency it frequently crops up again in the Budget Bureau, which must approve each of the Commission's budget items before they go to the Congress

Perhaps the most erroneous "guesstimate' the Commission has made—and certainly the largest dollarwise—had to do with the great Savannah River plant now building in South Carolina This plant involves a new process never before used, construction started long before the design work was more than ten-per-cent complete, many improvements have been incorporated as construction has progressed, and the size of the project has been substantially increased But the Congress, understandably, wanted to know how much this plant was finally going to cost before we started to work on it At that time—in December 1950—in response to a direct question I said I would say in the neighborhood of $600,000,000" But I added "I would hate to be frozen to that, because you must appreciate that the estimates we are making today are on the cost of production units that have never been built before"

By April 1951, four months later, the very tentative total cost estimate of the Savannah River plant had climbed to $900,000,000, and by September of the same year to

motivates most of these companies In some cases the fee is nothing more than a nominal amount, ranging downward to as little as $1 00 per year In other cases, no fee at all is paid—just the expenses of the job

Even so, both the government and industry would rather see the CPFF-type contract replaced entirely by a unit price or lump-sum type which would help shift the atomic energy industry over to a more competitive base where initiative and efficiency would be rewarded in terms of profit But the pioneering nature of the work, the great size of the projects involved, and the need for speed preclude this in many cases, at least for the time being

Another headache stemming from these same factors can readily be seen when one remembers that the Commission must obtain the money for these projects from the Congress, and that the Congress quite reasonably wants to know just exactly how much something is going to cost before appropriating the funds And yet in many cases the Commission simply cannot say with any real assurance If it waited until all of the final design work was done and then asked the Congress for the money, literally months, and sometimes years, would be lost in the process—years in which the Russian atomic energy program, we can be sure, would keep on building And if designs were arbitrarily frozen before construction was completed, the Commission would probably find its hands tied when it wanted to incorporate a newly discovered improvement that would greatly increase production efficiency

What the Commission must do, then, in most cases is to give the Congress its best guess as to the final cost when it submits its request for funds Understandably enough, this usually doesn't satisfy the appropriations committees, however Sometimes the Commission overestimates, and subsequently saves money that is returned to the federal treasury Most of the time, however, it underestimates

I have often wondered just why it is that the cost-esti-

just the right time and place All the structural steel, nickel, copper, cement, and lumber in the world are useless unless sufficient people are on hand who know how to put them together in just the right way And all the construction workers in the world are of no help in getting anything done if no materials are available

The problem, then, is one of synchronization, and synchronization isn't easy when you are dealing with trainload after trainload of materials and thousands upon thousands of workmen It becomes particularly difficult when many of the materials needed are hard to obtain and when some of the workmen feel constrained for one reason or another to stop work from time to time

On the whole, the atomic energy program has been remarkably free of work stoppages—a tribute to the loyalty and patriotism of American labor, and, during most of my term as Commission Chairman, to the fine work of the President's Atomic Energy Labor Relations Panel, headed by William H Davis This Panel has since been abolished and a new one with similar objectives set up under the Labor Department At the time of this writing, no work stoppages at all have occurred on the operations side of the atomic energy program, and relatively few have occurred in construction But the few that have occurred have hurt, and badly The worst situation prevailed at Paducah, where the Commission had to go to costly extremes to make up lost time Some of these work stoppages have occurred for reasons that one can sympathize with, although not with the acts themselves, but too many have involved such things as jurisdictional disputes between unions with which neither the government nor its contractors are directly concerned

The great steel strike of 1952 also took its toll in the atomic energy program, and not because any of the people on strike worked for the program directly, but rather because they worked for industries producing materials

$1,200,000,000 The September estimate was based on design work only ten-per-cent complete, although construction by then was well under way Now it looks as if the plant in its final form will cost about $1,500,000,000

This is not a pretty story, and I don't like it any better than the average taxpayer does It can be said, of course, that much of the increased cost is due to improvements incorporated after construction began, to substantial increases in scope and size, and to such factors as the need to pay premium prices for many of the critical materials involved But the fact remains that some bad estimates were made at the start There was every reason why the estimates should not have been accurate, but they nevertheless were too unrealistic to be rationalized in this way

I know, however, that the government is getting one dollar's worth of plant for every dollar invested in this project It is not that money is being wasted here Both the Commission and its contractor are seeing to that, and independent investigations sponsored by Congress have shown it to be true It is, instead, that the final costs were not figured accurately enough in advance But I don't think either the Commission or its contractor should be too severely censured for these poor cost guesses until all the returns are in If this plant, when completed, fails to do any better than it was originally designed to do, then I think the Commission can be fairly criticized for a bad mistake in estimating But if it does substantially better than it was at first designed to do—as I firmly believe it will, partly because of the costly improvements incorporated—then I would say our mistake was a relatively minor one compared with the end result, and can justifiably be forgiven

A good many of the other perplexing difficulties stemming from the urgent need for speed in the Commission's construction program have to do with the problem of bringing vast quantities of men and materials together at

gram would have to be worked out, something we found the Defense Department and the Office of Defense Mobilization somewhat reluctant to do at the time After a good many conferences between the Director of the Office of Defense Mobilization, the Secretary of Defense, and myself, however, a plan was developed whereby the Commission was given the right to a super-priority on materials up to a dollar amount of $55,000,000 over a period of twelve months Although this accounted for only a fraction of our total needs, it gave us the opportunity to obtain immediate service on our few key requirements, and the previously tight situation was consequently eased considerably

But a price has been paid at Savannah River, at Paducah, at Fernald, and elsewhere for the delays brought about by the tight materials situation and the work stoppages both within and without the Commission's program The price has been paid in both dollars and in time, and the repercussions of these difficulties have been felt throughout the entire construction effort By way of illustration, here is another headache the Commission encountered that was at least partly due to the difficulty of bringing everything together at just the right time and place

At Savannah River the Atomic Energy Commission figured in advance that the peak construction force, assuming everything went as scheduled, would total about 45,000 people It is obvious that no semi-remote area in the country can absorb an additional temporary population of this magnitude, particularly when one remembers that this figure does not include the families of workers So, as part of the total construction problem at Savannah River the Commission also faced the necessity of providing housing for these temporary workers and their families Here, again, was a problem of synchronization, for the additional housing had to be there when the need for the peak load of workers arrived Otherwise, the workers could not have

for the program The place hurt the most was the Savannah River plant, where very large quantities of structural steel were needed right at the time the effect of the strike was at its worst The steel workers in general were very good about keeping defense orders moving throughout the strike, but the work stoppage couldn't help but slow down even defense production For one thing, it took time to determine just what was defense work and just what was not, and, for another, it was very hard for the steel industry to meet specific defense demands when virtually all of its productive capacity was closed down

Even before the steel strike, however, the Commission had experienced a good deal of trouble getting structural steel and other critical materials for Savannah River on schedule But here it was a question of priorities rather than of material shortages The Commission could, and still can, get all the materials it needs because the National Production Authority has been very good about making allocations to the atomic energy program and then troubleshooting them through But since the Commission s priority was no better than the priority assigned all other defense work, of which there has been a great deal, this still wasn't good enough The urgent construction schedules in atomic energy often have not permitted the Commission the luxury of waiting in line, even when it could get in ahead of all non-defense orders What it wanted was the right to take delivery at several construction jobs on certain crucial items after a delay of no longer than industry required to produce them The Commission didn't want all of its orders filled in this way, naturally, but it did want a few where the need was especially urgent

This meant that, if there were to be no delay in the expansion program, the Atomic Energy Commission had to have a super-priority that would put at least some of its items ahead of most other defense work And this, in turn, meant that some relative priorities within the defense pro-

of landlord to the employees of its contractors, it chose to enter into contracts with private concerns for 4,000 trailers to house families, and four large barracks projects capable of accommodating 7,500 single men Under these contracts occupancy was guaranteed up to 90 per cent for the trailers and 100 per cent for the barracks for four years, with provision for earlier cancellation with payments to reimburse the contractors' losses

But three things went wrong Because of materials shortages, the peak employment turned out to be 39,000 instead of 45,000, an unprecedentedly large percentage of married men turned up on the job with their families (80 per cent instead of the usual 60 per cent), and the single men who arrived exhibited a marked preference for any kind of domicile as long as it wasn't a barracks

As a result, it was early decided that one of the four barracks projects planned would not be needed, and construction fortunately was canceled before it was started The other three, however, comprising 4,500 beds, were completed and placed in operation But the highest occupancy level reached in them was about 25 per cent They have subsequently been removed, therefore, and the contract with the private owner canceled To my knowledge, no one has yet come up with a good explanation as to why this departure from previous construction experience should have been encountered at Savannah River At Paducah, where barracks also were provided, the Commission's calculations, based on the same experience, came out just about right

In contrast to the barracks situation, the trailers at Savannah River have been remarkably successful Occupancy has been at or very close to 100 per cent ever since they were placed in service But there has been one slight headache there, too, in the form of an unanticipated cost resulting from an unforeseen and rather tardy action by the local rent-control board This board, after some of the

been obtained when they were needed, and the whole construction project would have been delayed at a cost of several million dollars a month while we provided the necessary housing This meant that the Commission had to determine in advance how much housing would be needed and what types it should be

To arrive at an answer, past experience on other very large construction projects was studied, and, with the cooperation of other government agencies, the Atomic Energy Commission surveyed the area to evaluate its capacity to absorb the temporary population It then estimated how many of the temporary workers would be single, how many would have families, how many children they would have, how much rent they would probably be willing to pay, how old they would be, and how many of them would be able and willing to find suitable housing of their own

Having done this, the Commission had two alternatives It could either provide the housing itself, taking a substantial loss when the time came to dispose of it, or it could enter into contracts with private concerns, guaranteeing them a minimum income large enough to realize a minimum profit The Atomic Energy Commission would naturally have much preferred to leave this entire problem in the lap of private enterprise, but the short period of time for which most of the housing would be needed eliminated this possibility No private operator would have had a chance of getting even his original investment back There was therefore no way of avoiding a government subsidy of some sort, one which the Commission figured would ultimately run, at a minimum, to between eight and nine million dollars, or about six tenths of one per cent of the total cost of the project It was estimated (and this was later borne out) that the cost to the government would be about the same whether it provided the housing itself or through contractors

Because of the Commission's policy of avoiding the role

a good deal of deliberation, therefore, the Commission authorized an extension of the work week at the Savannah River plant from forty-five to fifty-four hours for a period of eight months (It has since been reduced to an average of forty-nine hours per week) This helped to attract the needed workers, but it also meant that somewhat more had to be spent for labor than had been anticipated

An example of a different kind of overtime headache occurred in Nevada during the weapons test series in the spring of 1952, when the Atomic Energy Commission found one of its CPFF contractors—and therefore itself—paying a small group of electricians and plumbers wages ranging up to $800 per week The way they earned these fantastic wages, of course, was through overtime As it turned out, however, there was nothing irregular about the payment of these wages They were earned, and at standard hourly and overtime rates of pay negotiated with the union in advance There was no "golden time" or "double-double time" or fraud or anything like that Here is what happened

A few weeks before the test series was scheduled to begin, an urgent AEC-Department of Defense requirement developed for some knowledge that would importantly affect both weapons development and military planning, and that could be gained only by means of a special weapons test It was decided by the Atomic Energy Commission and the Department of Defense, with the President's approval, that this test should be held as soon as possible as a part of the series already planned The Atomic Energy Commission s people in Nevada were told to make the necessary preparations, which meant that some substantial modifications and additions had to be made to the structures and equipment being erected at the test site The scientists worked out what was needed and the construction people worked on their part of the job almost simultaneously

trailers were already occupied, placed a rental ceiling on them that was $22 50 per month below the figure we had guaranteed to the private concern owning them The government, therefore, is now making up the difference The Commission has appealed this action by the local board

There is reason to hope that the success of the trailer operation will compensate for the two million dollars or so that the low occupancy rate of the trailers may ultimately cost the government after final settlement charges are determined The barracks had best be forgotten One thing is certain the Commission learns as it goes along, and I suppose it is almost superfluous to add that it has no plans for barracks at the new Portsmouth site until concrete proof develops that they are needed

There are a good many other reasons why you will find packages of aspirin tablets in a large percentage of the desks around Commission headquarters in Washington, and a fair share of them come under the heading of "overtime" Overtime, because it is expensive, is something the Commission feels should be used only when absolutely necessary to get the job done This was the plan at Savannah River, which I like to use as an example because it encompasses just about every conceivable kind of situation The plan there was to avoid overtime except where it was absolutely unavoidable To this end, a forty-five-hour week was established and the Commission decided to stick to it, hiring enough men to do the job on that schedule But it wasn't quite as simple as that In the tight construction-labor market existing then, it was impossible to attract enough people who wanted to work only forty-five hours when there was plenty of other work available that involved more hours and therefore more pay In the construction field, where wages are more or less uniform and the demand in many places exceeds the supply, builders often must bid for workers' services with overtime After

men already on the site as hard and as long as they were willing and able to work This was done, and I believe he made the best possible decision under the circumstances Everyone connected with the operation can take real pride in the fact that when H-hour of the first test day arrived the now-familiar blindingly bright light filled the desert sky, a roar reverberated through the Nevada hills, and a great mushroom-shaped cloud billowed miles up into the air The deadline had been met, the test went off as planned, and the national security had been substantially advanced But the overtime incident was a headache just the same, and the Commission immediately took steps to keep the need for such extensive overtime from arising again

I have cited these few isolated, but more or less typical, examples of the headaches that go with a multibillion-dollar construction program as illustrations of the things that come along to harass the Commission as it tries to keep its mind and eyes focused on its main objective—optimum atomic strength in this country as soon as possible They are the kinds of headaches that grow out of the dramatic and nasty incidents that require attention far out of proportion to their significance to the total program You might think that barracks in South Carolina or plumbers in Nevada are rather far removed from the neutrons, reactors, and atomic bombs, but in actual practice they are not They are a necessary part of the great effort being carried on to give substance and meaning in terms of national security to the ideas that generate in the minds of our scientists

But time began to run out, and as the date for the start of the test series approached, the construction people had to work longer and longer hours to meet the completion deadline and still keep up with the scientists' last minute changes The burden fell most heavily on the electricians and plumbers, and particularly upon a few key supervisory people It was these supervisory people who received the fantastic wages, building up in the final week or two to as much as $800 To earn this, however, they had to work on an average of nearly twenty hours per day (twelve of them overtime), eating on the job and cat-napping when they could get the chance

Of course, it might be argued that it was not absolutely necessary to pay these enormous salaries to these few individuals But what were the other alternatives?

1 The test series could have been postponed at a measurable cost of $30,000 per day (expense of maintaining the many scientists, technicians, and construction workers at the site) and at an immeasurable cost to the national security

2 Additional workmen could have been brought in from Los Angeles, the nearest labor market of any size, which was 250 miles away This would have meant taking time to familiarize these new people with the job, as well as housing and feeding them in an already crowded desert site where men were sleeping in double-decker bunks, where the cafeteria was running around the clock, and where even the drinking water had to be hauled in from about eighty miles away In addition, according to standard industrial practice, the Commission would have had to pay the transportation of these new workers to and from the site

After taking a look at these alternatives, the Commission's test director decided that the simplest, most efficient, and most inexpensive course of action would be to meet the deadline on time, and to meet it by working the

"The atom bomb is the most horrible and fiendish weapon ever devised by man It's sinful for us to go on making them"

"The A-bomb doesn't amount to much, why, those soldiers out in Nevada were right up beside an explosion and weren't hurt at all They were laughing when it was over"

"Did you see where the atomic energy people blew up a whole island in the Pacific? Why, they wiped it right off the map!"

"Atom bombs are bad all right, but if you live a couple of miles away from the nearest target, you'll be okay"

"If the Russians ever decide to let go on us with A-bombs, there won't be a thing we can do except clobber them back Civil defense is just a waste of time—like throwing sand on a volcano"

'What I never could understand is why we didn't use a few A-bombs in Korea We could have blasted those Reds right out of those hills and back to China"

'A-bombs are like poison gas, both sides have them and both sides are afraid to use them"

"The H-bomb? I want to keep my sanity, let's talk about baseball"

Much of the confusion is undoubtedly due to the reticence of the Atomic Energy Commission—a reticence calculated to deny useful knowledge to our potential enemies Unfortunately, it also denies useful knowledge to our own people But it is impossible to give information to the American public without also giving it to those who would use it against us That is the dilemma, and it is generally solved by giving out certain basic information upon which reasonable and responsible people can reach valid conclusions, and withholding information that would help our possible enemies more than it would help us This is often hard to do, but it is the objective

I know there are those who say "Fuchs and those fel-

CHAPTER *vi*

The Payoff: Weapons

AT the end of the long, bustling atomic energy production line, with its far-flung exploration parties, remote mines, futuristic plants, and booming construction activity, lie the secret locations where our national stockpile of atomic weapons is stored These weapons are the end product They are what all the activity is about and what the production line is for By merely reposing quietly in their hidden vaults they affect the lives of all of us and influence the course of world events

There has probably been more talk about atomic weapons than about any other phase of atomic energy Yet, there is probably less real understanding of what atomic weapons are, what they can do, and how they affect us, than there is about any other part of the atomic energy program Too much of the talk is based on ignorance, too much of it is seasoned with speculation or sensationalism, and too much of it is garnished with fear or repulsion to make it very useful as a means of obtaining an objective understanding of what atomic weapons are really all about

It is not surprising, in such a setting, to hear such contradictory comments as the following

misleading, or because they are talking in areas where they have "no business" to talk As tempting as this solution is, it in many ways carries with it more dangers than the circulation of irresponsible reports, for governments that have engaged in this kind of activity have invariably found it hard to know where to stop The "misleading" books found in Germany by Hitler's Nazi government made quite a bonfire

Some of the misunderstanding about atomic weapons is probably also due to the small amount of experience the public has had with them Fortunately, none has ever been exploded in the United States except under controlled test conditions Of the at least forty-nine that have been detonated in various parts of the world, only six have been seen and studied by people not connected with the atomic energy programs or armed services of the United States, Great Britain, or the Soviet Union Here is a chronology of the atomic explosions that have taken place throughout the world up to the time of this writing

1945 Total of 3, all by the U S, at Alamagordo, Hiroshima, and Nagasaki

1946 Total of 2, both by the U S, at Bikini Atoll in the Pacific

1947 None

1948 Total of 3, all by the U S, at Eniwetok Atoll in the Pacific

1949 Total of 1, by the U S S R, "somewhere in the Soviet Union"

1950 None

1951 Total of 18, including 12 by the U S in Nevada, 4 by the U S at Eniwetok, 2 by the U S S R

1952 Total of at least 11, including 8 by the U S in Nevada, at least 2 * by the U S at Eniwetok, 1 by the British at Monte Bello Island, Australia

1953, up to July 1 Total of 11, all by the U S in Nevada

* Exact number confidential at this writing

lows stole most of our old wartime secrets and gave them to the Russians, why not publish this information so our own people will know at least as much as the Russians?" This is good reasoning so far as it goes, except for one fatal fallacy Spies, like the rest of us, are only human, and the information they pass on is subject to distortion and misinterpretation, just like the gossip at last night's bridge party or the report in yesterday's paper It might just be that an official announcement over here could clear up the one point in a spy's report that had been left out or wrongly interpreted But in any event, it is not so much the technical secrets on how to make weapons that help public understanding as it is information on what atomic bombs can do

Part of the confusion about weapons, in my opinion, is due to those people outside of the program (some of them well meaning) who have discovered that one can attract headline attention, and therefore a certain kind of fame, by saying things publicly about atomic bombs It is a case of the self-styled expert rushing in where the government, for security reasons, fears to tread Some of what these people say is true, a good deal of it is not While this may be good for the national security, in that it may confuse our competitors, it is scarcely good for public understanding And yet the government cannot censor the writings and utterances of these people in detail, for to do so would be to tell them exactly what the real secrets are and thus leave them free to pass the truth on to their friends or acquaintances, or perhaps even to publish it Their demonstrated irresponsibility does not recommend them as good security risks By the same token, the government also cannot publicly correct their misleading reports, for to do that would be to broadcast the secret we are trying to protect

Sometimes I have heard it said that the government should censor these people just because what they say is

misleading, or because they are talking in areas where they have "no business" to talk As tempting as this solution is, it in many ways carries with it more dangers than the circulation of irresponsible reports, for governments that have engaged in this kind of activity have invariably found it hard to know where to stop The "misleading" books found in Germany by Hitler's Nazi government made quite a bonfire

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Of all these, only the ones at Hiroshima and Nagasaki in 1945, the two at Bikini in 1946, and one each in the 1952 and 1953 series in Nevada have been seen relatively close up by unofficial observers This is not, unfortunately, a very broad base upon which to build an accurate public understanding of atomic weapons and their capabilities There will be more "open" shots, and there should be

While the general paucity of official information on weapons has restricted public understanding to some degree, perhaps the most important obstacle results from the fact that atomic energy began as an entirely secret project which burst into world consciousness in the most spectacular and violent kind of way Consequently, too many people still consider atomic weapons to be too secret to mention, or too horrible to contemplate, and they therefore close their minds to the authoritative facts the government has released to them Too many others, apparently remembering Hiroshima, are inclined to believe every sensational report they hear, no matter what the source is, and the government's official remarks become lost in a general sea of rumor and speculation

I think it is possible to bring some sense out of all this, and I shall attempt to do so later on in this chapter But as part of the background, I believe it would be useful to look at some history

To date, two atomic bombs, and only two, have been used as weapons of war They were used not as so-called 'tactical weapons' against troops in the field, but as "strategic weapons" delivered against the power of an embattled nation to continue to make war They were used by the United States, and they were delivered by aircraft operating in skies over which we had won control and against an adversary who was not capable of retaliating either in kind or in any other effective way against our homeland

As a result of the use of these bombs, two Japanese cities of moderate size were destroyed, with 100,000 f-

ties, and six days after the second attack the Japanese nation, which had previously given every indication that it would continue to resist even an invasion, surrendered.

It is generally accepted as a fact that there was a direct relationship between these two events, and I am one of those who believe this to be true. I believe this, not because the destruction wrought by the atomic explosions at Hiroshima and Nagasaki was so great as to cripple the Japanese war machine to the point where it could no longer continue to fight—because it obviously wasn't—but rather because the United States had demonstrated that it possessed an awesomely destructive new weapon and was capable of using it.

The Japanese had seen thousands of aircraft over their cities and had felt the impact of the conventional weapons they carried. They were apparently totally unprepared, both physically and psychologically, to cope with a situation where these thousands of aircraft might be carrying the new and terrifyingly powerful weapons they had seen demonstrated at Hiroshima and Nagasaki. To withstand attacks with conventional weapons in great numbers, including fire bombs, or even to fight fanatically and suicidally for every inch of their homeland was to the Japanese one thing, but to sit impotently by while Japan was pulverized into a desolate wasteland was, apparently, quite another.

Perhaps if the Japanese government had known the exact size of our stockpile in August 1945 (after the attacks, it was virtually nonexistent), they would not have surrendered short of an invasion. But they did surrender. This fact, I feel, has ever since had a direct bearing on the way in which atomic bombs have been viewed, not only by the peoples of the world, but also by a good many of the world's military strategists and diplomats, including some of our own.

The Japanese surrender, then, found the United States

in the uniquely favorable position of being the sole possessor of a weapon that was almost universally credited with a capacity to destroy cities on a ratio of one bomb per city, and to end wars on a ratio of two bombs per war. It is an interesting and, I think, complimentary comment on the character of the American people that our principal reaction to this turn of events was one of acute embarrassment. Many spokesmen for the American scientific community stated quite candidly that they entertained grave misgivings about the role they had played in unleashing this terrible new force upon the world. The atomic bomb was often called "the absolute weapon," "the forerunner of Armageddon," and "a glimpse of Hades itself." Many of our most eminent clergymen and civic leaders openly questioned the morality of using such an obviously horrible weapon. And, in an unprecedented action, the United States formally offered to the United Nations a plan whereby we would give up the atomic bomb and place atomic energy under international control.

By these means, with the best intentions in the world, we proceeded to augment the impression, already created by Hiroshima and Nagasaki, that here was a weapon that was worse than all other weapons, and somehow worse than war itself. Under this kind of reasoning, carried to its extreme, it becomes much less of a crime wantonly to invade your neighbor, burn his cities, and murder his women and children, than it does to use an atomic bomb in your own defense. Meanwhile, in the absence of international control, and with the realization that the distasteful atomic bomb still constituted a bulwark against the aggressive designs of Soviet Communism, we proceeded to develop bigger and better bombs and build up a stockpile of them ready for use by our strategic air forces if the occasion arose. With the demobilization of our military forces in Europe, the Far East, and at home, this

stockpile, paradoxically, became the most important single factor in our strategic defense planning

All of this had both good and bad effects On the bad side, I would say, was the fact that we succeeded admirably—aided by eager Russian propagandists—in working ourselves into a position where the most important single ingredient in our defense arsenal was tucked away where it couldn't be taken out, except under the most extreme conditions, without a good deal of soul-searching at home and a loss in our reputation for morality abroad No one appreciated this situation more than the Russians By means of it, they were given a much greater freedom of action in the postwar world than they would otherwise have enjoyed They were, because of the wraps in which our A-bombs were kept and our general weakness in other areas, free to create a seemingly endless series of what from our point of view were serious, but nonetheless subcritical, situations which did not involve for the Russians the risk of atomic obliteration, but yet had an excellent chance of redounding to their benefit

On the good side was the fact—and I am among those who firmly believe it is a fact—that our atomic monopoly and our stockpile of bombs for strategic use was a deterrent to the Russians in that it made it impossible, or at least foolhardy, for them to commit the irrevocable act that would bring on all-out war They tried to do just about everything they could get away with short of bringing on all-out war Our atomic stockpile, therefore, probably more than anything else, brought the free world safely through the postwar years when we were woefully weak in conventional arms

An enormously important new factor was introduced into this world situation in 1949, when the first atomic explosion took place in the Soviet Union This may not have been too important in itself, for it is a long way from a first test bomb to a significant stockpile But it was

of the utmost importance so far as the future was concerned, for it meant that one day the Russians would undoubtedly have enough bombs to deliver an atomic attack on the United States and the other countries of the free world, if they chose to do so Thus, since 1949, we have been watching the value of the main ingredient in our national defense arsenal gradually diminish as the Russians build toward a stockpile of atomic bombs which they may well feel, no matter how crude their design, will someday reach sufficient proportions to cancel out the atom as an instrument of warfare If such an impasse occurs, the United States would appear to be left in a rather unenviable position The most useful product of our technological competence would appear to be lost to us, except as a deterrent to the use of A-bombs by the enemy, and the Russians would appear to be free to take full advantage, in world military and diplomatic affairs, of their vast superiority in man power and their highly favorable strategic position dominating the Eurasian land mass

The atomic impasse I have described here could, of course, be upset at any time, in favor of either side, by improvements in modes of defense and means of delivery A stockpile of bombs big enough to destroy every inch of an enemy's industrial heartland would be of little value unless the means existed for getting these bombs through the defenses and on to the target I hope sincerely that in this competition the free world will always have the lead, and I hope that no sense of false economy will slow that lead It would be unrealistic, however, to count on this lead always being on our side, or always being significant enough to guarantee complete immunity from attack The gloomy truth is that anyone who possesses a large stockpile of atomic bombs will in all likelihood possess also the means of getting at least some of them—and probably a good percentage—through to the target

I have described what I consider to be an unhappy state

of affairs But fortunately the factor of the Russian bomb is not the last factor to be introduced into this atomic military equation If you will recall the chronology given earlier in this chaper, you will note that in 1951 another rather noteworthy development took place Whereas from 1945 to 1950 only seven test bombs were set off in the world, in the year 1951 sixteen were detonated by the United States alone There was a reason for this sudden burst of test activity because of some brilliant research and development work at the Los Alamos Scientific Laboratory, it became possible for the military services to begin to think of the atomic bomb in terms of a battlefield weapon, and not just something that is delivered by intercontinental bombers or guided missiles against the industrial heartland of an enemy A good many of the tests held in 1951, and since then, have therefore been for the purpose of developing new varieties of atomic weapons suitable for use by troops in the field, by aircraft supporting these ground forces, and by navies In this country many troops have been trained as part of these operations

What effect does the introduction of this new factor have on the impasse we appear to be drifting toward in the strategic use of atomic bombs? Briefly, it could mean that, while we might be unwilling to use our bombs strategically against Russia for fear of retaliation, and Russia might be unwilling to use hers against us for the same reason, we would nevertheless be in a position to use our tactical weapons in the field, thus so increasing the firepower of our forces that Russian man-power superiority would be virtually canceled out Under this line of reasoning, our atomic stockpile once again becomes a deterrent, not only to an atomic attack against us, but also to an act of major aggression against us or our allies with conventional arms

In answer to this, one might of course say "But if we used atomic weapons in any form at all—even tactically in

the field—shouldn't we expect the Russians to retaliate with a strategic attack against the United States interior, or against our allies, assuming they were in a position to do so?" I can only reply that if I were a Russian I would certainly think twice before I did so. Our retaliation against the Russian heartland in such an event would be terrifying.

One might also ask: "But isn't it possible for the Russians to make these tactical weapons and use them against our troops in the field?" Of course, it is possible. But the important thing to remember here is that, even in that event, we will have succeeded in getting the competition back on a basis where the premium is no longer on man power, where we are at our weakest, but rather on technological competence and production capacity, where we are at our best. As to how this race is going at present, I point only to the wide disparity in the number of tests held by the two countries to date, and tests are an important and necessary part of any weapons development program.

Another question one might logically ask is: "But wouldn't the moral inhibitions associated with the strategic use of atomic weapons also apply to their use in a tactical way?" My answer would be that they should not. The specter of Hiroshima and Nagasaki should not hang over the tactical use of atomic weapons against military men, particularly those engaged in an aggressive act. The mass killing of millions of women and children and the fear of retaliation in kind is, in my view, what causes most people to be more revolted and horrified by the thought of atomic warfare than they apparently are by the thought of warfare *per se*. But none of these things would appear to apply to the use of atomic weapons against troops. Napalm (jellied gasoline used as incendiaries) is a fearsome weapon, but there is no international revulsion against its use on the battlefield, and I don't think there

should be any revulsion against the tactical use of atomic weapons Rather than a feeling of revulsion, there should, in my opinion, be a feeling of relief that a way has been found to resist aggression without all of the horrors normally associated with atomic war

By all this I do not mean to imply that, even under the conditions I have described here, we would no longer have need for strategic weapons Far from it We would, if for no other reason, need them to keep them from being used against us And, if they were used against us, we would need them as a means of instant and effective retaliation We might also need them for use against major, purely military targets in various parts of the territory controlled by the enemy

There is, of course, one other factor affecting the world distribution of power in the field of atomic weapons, and this is the so called hydrogen or 'thermonuclear" bomb, about which the self-styled experts have had a good deal to say But if the government's official attitude toward public discussion of atomic weapons of the more conventional type is one of reticence, its position on information about the hydrogen bomb can be described as one of virtually complete silence This is about all that has been said officially

1 On January 31, 1950, the President announced that he had directed the Atomic Energy Commission to continue its work on all forms of weapons, "including the so-called hydrogen bomb"

2 On May 25, 1951, the Commission announced that a series of weapons tests had been successfully carried out at Eniwetok The announcement contained this sentence "In furtherance of the President's announcement of January 31, 1950, the test program included experiments contributing to thermonuclear weapons research"

3 On November 16, 1952, the Commission announced that another series of weapons tests had been completed

at Eniwetok Again the announcement contained this sentence "In furtherance of the President's announcement of January 31, 1950, the test program included experiments contributing to thermonuclear weapons research"

4 In his final State of the Union message on January 7, 1953, President Truman said "And recently in the thermonuclear tests at Eniwetok, we have entered another stage in the world-shaking development of atomic energy From now on man moves into a new era of destructive power, capable of creating explosions of a new order of magnitude, dwarfing the mushroom clouds of Hiroshima and Nagasaki"

I think it is obvious from all this that we have not been going backward in the H-bomb field, and that it is only prudent to assume that a stockpile of workable H-bombs can be accumulated And this should be remembered If we can do it, there is no reason to believe that others can t The H-bomb, therefore, is a new factor in our atomic military equation that must be taken into account It is quite possible that it may tip the scales temporarily in our favor, but it can t be for long

There has been some controversy among experts about the real significance of the H-bomb In weighing its importance, two things are worth remembering First, it can be designed to be many times more powerful than the most powerful A-bomb, and second, although it requires an A-bomb to set it off, its extra power is obtained from the use of materials that are plentiful in nature Theoretically, such a bomb can be made as destructive as one wishes, but this is not a very meaningful kind of statement, for, again theoretically, one could also make a TNT explosion as big as one wished by simply adding more explosive material But from the practical standpoint, there are in both cases some real limitations having to do with such things as design, deliverability, military usefulness, and comon sense

Although it is probably of but small comfort, there is one practical limitation on the destructive effects that can be attained on earth by an explosion This arises from the fact that the main force of any explosion travels in the line of least resistance For a bomb explosion, this line is upward into the atmosphere It is therefore theoretically possible to make an explosion so big that the main force of the blast would penetrate the earth's envelope of air and be dissipated harmlessly in space Certainly there is very little point for anyone to make a bomb with an explosive force bigger than this, no matter how evil or maniacal his intentions

Another small ray of hope stems from the fact that the radius of blast damage for any kind of an explosion increases at a much smaller rate than the rate by which the power of the explosion is raised The damage radius is actually increased by a figure equal to the cube root of the figure representing the increase in the power of the explosion Thus, if one were to multiply the explosive force of any given bomb 125 times, the radius of damage would be increased but five times, five being the cube root of 125 And, by the same token, if one multiplied the power of any given bomb a thousand times, the radius of damage would be increased but ten times In the case of the Hiroshima bomb, the radius of almost total destruction was about one mile For a bomb a thousand times as powerful, therefore, the radius of almost total destruction would be about ten miles It is clear from all this, I believe, that there is a law of diminishing returns working on the side of humanity

On the gloomy side, however, is the fact that a hydrogen bomb can be deliberately rigged with certain materials that would be made very highly radioactive by the explosion and disseminated by it into the atmosphere and over the surface of the earth for thousands of miles in the direction of the prevailing winds These materials

would have a deadly effect on all living things with which they came in contact But there is a ray of hope even here Anyone who used such a fiendish device would have a very difficult time making sure that he himself might not be subjected to a "boomerang" effect from air currents over which he had no control and could not predict with complete accuracy in advance The prudence, or even the military value, of such an inhumane device would be open to serious question, even for one obsessed with the mad dream of world conquest Used in this way, the H-bomb would not be a weapon of war, it would be an instrument for the destruction of civilization and possibly of all mankind

One way of considering the value of the H-bomb as a practical weapon of war is to ask oneself the question "Would I rather live in a city that was hit by one H-bomb or a hundred A-bombs?' The answer is, of course, that none of us would want to live in a city that was hit by either To the man in the target city it makes little difference whether he is attacked by one or two H-bombs or a basketful of A-bombs adding up to the equivalent destructive effect But to the man who launches the attack the H-bomb has a certain value, particularly in the case of very large and important targets It means, for example, that he can either launch but a fraction of the carriers (aircraft or guided missiles) that he would otherwise need, or that he can afford much greater losses among his carriers and still deliver a knockout blow It also means that, if he is short of fissionable material or wishes to save it for other uses, such as in smaller weapons against troops, he can get a lot more destruction out of it in H-bombs than he could if he used it exclusively in more conventional atomic weapons It is in relation to considerations like these that the H-bomb begins to have real meaning to the military man

I promised earlier in this chapter to try to bring some

sense out of the welter of words that have been spoken and written about atomic weapons In the perspective of the historic trends just discussed, the following facts and conclusions seem to me to be pertinent

1 Two atomic bombs have been detonated in war The power of these bombs has been officially disclosed Each was equivalent to about twenty thousand tons of TNT

2 The effects of these bombs, which were detonated in the air above the target, are well known Of the casualties, most were due to such secondary effects as flying debris and induced fires, as has been the case in all other high-explosive bombing attacks These effects can be minimized by effective civil-defense measures Of the direct effects of the bombs, the most important from the standpoint of casualties was heat Next was blast Last was radiation All of these can be minimized by effective civil-defense measures, including particularly the deployment of the population from the target area It is known that the other effect of an atomic attack, the deposition of radioactive dust particles, was not very important at either Hiroshima or Nagasaki The towns were reoccupied shortly after the attacks without harm to those returning

3 It has been learned from postwar tests and calculations that the area of damage resulting from an A-bomb explosion is substantially reduced in the case of underground or underwater detonations, and that the lethal effect or residual radioactivity is substantially increased Total casualties might be greater or smaller depending upon a number of factors, such as disposition of the population, location of the detonation, wind direction, size of the bomb, and so on The effect of residual radioactivity, however, like the other effects, can be minimized by effective civil-defense measures (such as baths, removal of contaminated clothing, consumption only of foodstuffs that have been protected by containers, and decontamination of surfaces with detergents, soaps, and water)

4 Of the four atomic detonations since World War II to which unofficial observers, including representatives of the press, have been admitted, all have been in the energy range of from seventy-five per cent of the force of the Hiroshima blast to about double that force This, then, is the power range with which the world is most familiar The government, however, has announced that we possess bombs many times more powerful than those used in World War II It has also announced that we have bombs somewhat less powerful than those used in Hiroshima and Nagasaki An atomic explosion, however, no matter how small in power, is a big one when compared with more conventional types

5 It is well known that the United States is developing a variety of atomic weapons designed to meet a wide range of target situations The government has said that we are working toward the day when we will have atomic weapons in almost as complete a variety as we have conventional ones, that is, in the form of artillery shells, guided missiles, naval weapons, very large bombs for use against big targets, and smaller bombs for use against smaller targets It is our objective to have on hand sufficient strategic weapons to destroy completely an aggressor s industrial capability to make war, plus enough for tactical use to stop in the field any aggressive move he might make

6 In our efforts to develop a variety of weapons, we have since 1951 had thirty-one weapons tests at Nevada and at least six at Eniwetok involving devices of varying destructive power It has become known that in the series in Nevada this spring one of the weapons tested was an atomic shell for an artillery piece

7 As to our progress in achieving the stockpile we need, it is known that our current reserve is sufficiently large for the government to begin talking about diverting some fissionable material to such peaceful use as the de-

velopment of power-producing reactors As we have seen, however, the Atomic Energy Commission is currently engaged in a huge expansion program, a fact which clearly suggests the stockpile is still not as large as we would like it to be The government has made it plain that completion of these expanded facilities on a very high priority schedule will enable us to meet our minimum military stockpile requirements four years sooner than would otherwise be the case

8 It has been announced that two tests in connection with the development of the H-bomb have been held, and that progress has been sufficient for the government to say that "we have entered another stage in the world-shaking development of atomic energy"

9 Soviet Russia, our hostile competitor, is also in the business of manufacturing atomic weapons, and has been since 1949 This does constitute a threat Although we obviously hold a substantial lead over the Soviets, this is hardly an effective means of preventing them from accumulating enough bombs to deliver a knockout blow against us It is true that the Russians have held but three tests at this writing, but this should not be a cause for complacency Whereas such a small amount of test activity might well indicate a lack of variety, it can hardly be taken as an indication of a lack of quantity, for tests are a necessary part of developmental rather than production activity

10 As the atomic stockpiles on both sides of the Iron Curtain continue to grow, leadership in the fields of atomic defense and delivery plays an increasingly important part in the world distribution of atomic power

11 Taking world progress in atomic weapons manufacture and development into account, it is no longer realistic to think of such weapons as something so rare and expensive that they will necessarily have to be expended one at a time, or that their explosive power will

bear some fixed relationship to the bombs we have known in the past Atomic weapons are absolute weapons, whether the target is a supply dump, a regiment, or a whole nation The only realistic way to plan our defenses, therefore, including civil defense, is to assume that atomic *weapons, if used against us at all, will be used in sufficient* quantity and size to destroy thoroughly whatever target they are aimed at The effects would probably be of the same type as those resulting from the blasts at Hiroshima and Nagasaki, but the degree might well be vastly different

What does all this mean to you as an American citizen? What should be the program for survival for you and for our country in this age of atomic weapons? My proposal would include these points

1 Whether you are a statesman or an ordinary citizen, you can work for and support the efforts being made to bring a real and stable peace to the world through the settlement of the differences now existing between nations and the reduction and international control of armaments

2 In the absence of a real international settlement, you can support and work on behalf of this country's effort to reach as soon as possible its minimum military requirements for atomic weapons and the means of delivering them The purpose of our weapons now, and their purpose in the future, is to deter war and aggression If we can have on hand enough weapons to destroy an aggressor's industrial ability to make war, and to knock out his invading forces in the field, we will have done much to ease the threat of war by making aggression so unprofitable that no prudent government would attempt it With a stockpile of weapons for strategic use we can deter a direct attack on our homeland, and with a stockpile of weapons for tactical use we can help deter such adventurous excursions as have taken place in recent years along the borders of the free and slave worlds

3 You can work for and support the efforts being made to strengthen the air defense of our country, including such things as radar screens, interceptor aircraft, and missiles, and—of great importance—civilian ground observer stations The more difficult we make it for an enemy to get through to his target with enough bombs to make the attack worth while, the larger will be the force he must launch, and the smaller will be the chance he will launch it

4 You can work for and support the efforts being made to give this country a strong civil-defense program A good civil-defense program means fewer casualties, perhaps fifty per cent fewer, and less property damage in case of attack The more damage and casualties are minimized, the harder it becomes for the enemy to launch a knockout blow, and the smaller is the chance he will attempt to launch it A good civil-defense program is a vital part of our national strategic planning, even if it never has to be used in an emergency By participating in your local civil-defense activity, you may not only be increasing the chances of yourself and your loved ones to survive in case of an attack, you may also be helping to prevent the attack from occurring in the first place Rest assured, your efforts are being considered in the calculations of those who would do us harm The hunter does not want merely to wound the lion, for his own safety's sake he wants to kill it with one blow So it would be in an all-out atomic war, our adversary will want to kill us, not merely wound us, and the harder you make it for him to accomplish this, the smaller is the chance he will attack at all

There is a sign I have seen along many highways in our country It reads "Drive carefully, the life you save may be your own" This is good advice, and we might all take it—ourselves, our allies, and our potential enemies—and apply it to the atomic age 'Think carefully, act wisely, the life you save may be your own"

CHAPTER *vii*

The Military and the Atom

THE ATOMIC ENERGY COMMISSION is a civilian organization The law creating it was written that way, and I, for one, hope that, in this respect at least, it will never be rewritten If, however, the military establishment is to be trained in the use of atomic weapons, and if we are to achieve atomic readiness, there must be the closest possible relationship between the military and the Commission In this chapter I will indicate how this relationship is achieved, and how it might be improved in some respects To do this is to raise questions that go beyond the military's role in the atomic energy program and touch upon our total national security

Top Russian military strategists cannot help but have a fairly accurate notion of our atomic weapon strength In my opinion this has been sufficient to deter them from any full-scale aggressions which they may have planned for the continents of Europe and Asia It follows that if we would continue to deter them we must remain strong It does not follow, however, that we need match them twenty to one, or ten to one, or even one to one, in atomic bombs forever—certainly not if deterrence is our primary objective, as indeed it should be Simply staying "ahead"

of the Russians, or even "far ahead" of them, is not the goal The weapons goal for the United States should be a sizable stockpile, no matter what the Russian stockpile may be Deterrence is accomplished when a sizable number is reached, for "sizable" means that point where an enemy, calculating the risk of retaliation, says to himself "No matter how many atomic bombs I may be able to deliver on the cities and on the industrial and military targets of the United States and its allies, I simply cannot afford to take the punishment which retaliation by the United States would bring"

The Russian military and political leaders no doubt made this calculation several times in the days prior to 1949, that is, before they had any bombs, and concluded that they could not take the retaliation which all-out aggression would bring upon them In the days since then, with a few bombs, they have obviously reached the same conclusion Can they reach any other conclusion five or ten years from now? It is unlikely For if we assume that the capacity to deliver bombs on targets bears some fixed relationship to the growth of the stockpile, the potential retaliation becomes increasingly unbearable to contemplate

If deterrence of an all-out Soviet attack has been accomplished, let us say with hundreds or a few thousand bombs (enough to obliterate virtually every city and industrial center in the U S S R), just how much greater is the deterrence accomplished by a stockpile of hundreds of thousands of atomic bombs? I venture to suggest that if one is to argue for stockpiles of this size, he cannot do so on the ground that he simply wishes to deter a wholesale aggression

What other considerations are there, then, that dictate the ultimate size of a stockpile or the rate at which we add to such a stockpile? When we say that someone has been deterred we assume that he has made a hard,

shrewd, calculated estimate of the risk and concluded that the risk isn't worth the candle Russian military and political leaders have generally been careful measurers of risk But let us suppose that an incident or an entire chain of now unforeseeable incidents should suddenly shape up in such a way as to bring on an all out war Let us suppose, for example, that a Russian Hitler should come to a position of great power—a man emotionally unbalanced, a moody, egocentric man with a mad impulse to take his country into a world war Let us assume that he cannot be restrained by his more reasoning associates This has happened before and it can happen again Such people are not deterred In this connection the words of David Dallin are sobering

'A stage is being rapidly reached in developments where only a broad retreat from global positions can save Russia and the world from unparalleled catastrophe The Soviet government, however, has maneuvered itself into a position of artificial and inflated prestige from which there is no backing down without great losses and without a crisis on the home front History teaches—and it is a sad lesson—that tensions of such magnitude are seldom resolved by peaceful means"

Should such a situation as we have envisaged come about, what kind of a stockpile should we have in our possession? We should clearly have a sufficient number to smash the aggressor hard and fast first at those points which offer the greatest threat to attack upon our homeland and the homelands of our allies, next, if need be, at those points in his industrial heart from which he must draw his power to strike later In the event of all-out atomic war the goal is simple—to end the conflict decisively and speedily Any other concept would be unthinkable Any plan which assumes prolonged periods of strife—periods in which one power will have months and years in which to organize such large transoceanic logistic feats

as characterized World War I and World War II—makes no sense at all To think of some mythical Mobilization Day when plants now in stand-by will be reactivated, or plants producing civilian goods will convert their assembly lines to items of war while atomic bombs rain about them, is utterly unrealistic

In the event of another world war there will be little or no time for such scrambling about as has marked previous M-days We must be ready if war should come—not ready to get ready Never again will this country have the luxury, if that it be, of two or three years in which to build from the utter weakness of a Pearl Harbor day to the overpowering strength of an armistice day Never again We shall have to fight with what we have at the outbreak of war

Recognizing this, the United States has within the past few years planned for, and to a considerable extent actually built up its military strength for, such an eventuality The heavy impact of this build-up will remain with us for several years to come And so will the atomic energy segment of it

During the past two years the annual federal budget has grown from 44 to 85 billion dollars, and the amount spent each year on atomic energy has increased from 900 million to 1,800 million dollars As evidence of the further projected growth of the atomic energy program, the Congress in the past two years has appropriated over five billion dollars to the Commission, of which about three billion is for use in getting a new expansion under way

Such dollar expenditures as these grow in large part out of military requirements It is important that we understand how these requirements are arrived at and what the civilian representatives in the government do or do not do with respect to evaluating them and implementing them

The fact that we are putting a great effort into getting

ready for a war, if it should come, before and not after it hits us, has raised the military establishment to a position of peacetime power and prominence which in other times it enjoyed only during a war The military today is necessarily involved in practically every phase of our internal industrial effort It has a direct hand in the manufacturing of goods to equip our armed forces And because of the various relationships which must be carried on with our allies, the military services have become entangled in virtually every phase of our foreign policy It is important that the nature of this increased participation be understood, and that it be seriously examined Let us consider it in connection with the military's relationship to the atomic energy program

In 1946 when the members of the United States Congress (and they included some very wise men, with some very wise consultants) were drafting a statute to create an Atomic Energy Commission, one of the basic questions they faced was whether such an enterprise should remain in the hands of the military or in the hands of civilians

The Manhattan Engineer District had been a military project It had called upon the best industrial and scientific talent It had operated in complete secrecy, and it had produced an atomic bomb in an amazingly short time In other words, it had been a success Why then, change the control? Why not leave atomic energy with the Corps of Engineers?

One obvious answer was that the entire atmosphere had changed with the ending of the war Peace and "normalcy" had returned Scientists who during the war had patriotically put up with the frustrations which frequently stem from military dominance, would simply not take it in years of peace There was a very widely held belief, too, that progress in atomic energy research and development would be severely restricted if left in military hands, because the scientific problems involved in a fast-moving,

little-explored field were beyond the scope, the competence, and the traditional area of responsibility of the military Secretary of War Patterson, for example, told the House Military Affairs Committee on October 9, 1945 "The War Department has taken the initiative in proposing that it be divested of the great authority that goes with the control of atomic energy, because it recognizes that the problems we now face go far beyond the purely military sphere" On February 14, 1946, in testimony before the Special Senate Committee on Atomic Energy he said "Continuation [of control by the War Department] is not calculated to advance fully the research and development of peacetime uses of atomic energy "

A group of seventeen organizations including the Federation of Atomic Scientists issued the following statement "Civilian control is essential to scientific progress You cannot order discoveries at the rate of so many per month An atmosphere of free exploration, of unfettered research, of freely exchanged scientific knowledge is the prime requisite for scientific advancement"

There was also the belief that permanent military control of atomic energy would not be in keeping with the traditions of American democracy, which provide that important policy-making functions should be in the hands of civilian authorities In fact, as Alfred Friendly of the *Washington Post*, who had followed closely the various legislative proposals for atomic energy control, observed "The most confusing aspect of the controversy now raging over civilian versus military control of atomic energy is the fact that all the disputants say they favor civilian control"

When the Atomic Energy Act of 1946 (the McMahon Act) was adopted, it incorporated two widely accepted basic premises first, that atomic energy should be under civilian control, and second, that there should be adequate opportunity for the military to follow closely and partici-

pate in those phases of atomic energy development having to do with military applications

Under the law it is clearly the business of the military establishment to tell the Commission the military characteristics of the weapons it desires, and, correspondingly, it is the responsibility of the Commission to develop weapons with such characteristics It is also clearly the business of the military to recommend to the civilian Secretary of Defense and to the Commission, to the Bureau of the Budget, and the Congress the number of weapons it needs in order adequately to defend the United States in the event of war But it can only be, and should be, a "recommendation" that the Defense Department makes—not a requirement which can never be questioned It then becomes the business of various civilian agencies to weigh these recommendations

Military leaders of stature have been the first to recognize this division of authority and responsibility General Bradley, for example, in testifying in behalf of increased expansion for atomic energy on June 16, 1952, before the Appropriations Subcommittee of the House of Representatives, stated " As I have said to many committees up here, we recommend what we think is needed from the military point of view You people and others are better qualified to know and to have the facts on the effect of this spending than we are We can only make a recommendation We are your military advisers We recommend certain things If you do not want to follow the recommendation, because of other reasons, we understand that We do not want this country to spend itself into bankruptcy, either We are citizens We realize it would be just as bad to lose our freedom by default as it would be to lose it some other way"

But let us return later to this broad question of civilian responsibility for total national security, and examine now for a moment the extent to which the military has tended

to concern itself with the detailed business of the civilian Commission

Once a military recommendation regarding weapons has been approved by the Secretary of Defense and the President, it is usually stated in terms of so many bombs of certain types by certain dates The Commission then goes to work to do the job The production schedules which result are frequently tight, sometimes back-breaking They involve all sorts of juggling of assignments within our own program They involve hundreds of delicate readjustments Too frequently, in the midst of all this, we find the military suggesting not simply *what* the Commission should do but also *how* it should be done This the Commission has resisted

The internal operation of atomic energy laboratories, how ore is obtained, the price paid for it, the countries from which it it should be purchased, the process by which it should be extracted—these clearly are the responsibilities of the Commission Any desire on the part of the military to control what is legally and properly under civilian control does violence to the concepts of such military statesmen as General Bradley, who has said

'[The Defense budget] is not in reality a military budget, it is a civilian budget Civilians are in charge In the Defense Department, the budget is controlled and finally approved, not by the Joint Chiefs of Staff but by the four civilian secretaries In the White House, it is carefully reviewed and inspected, and even changed, by an all-civilian Bureau of the Budget After it goes to Congress, the budget undergoes careful examination by the appropriations committees of the House and Senate This would not appear to me to be dangerous military control over the share of the Government's money which is being expended for defense, nor a dangerous 'military influence' on our economic life

"In our international negotiations, some of our great de-

cisions are influenced by recommendations of the Joint Chiefs of Staff—our four top military leaders But this dependence on military counsel is not of the soldiers' choosing All the military men I know believe profoundly in civilian control and look to civilian leadership in national and international affairs

"But in international affairs, just as in matters of the defense budget, civilians make the final decisions" *

If we depart from this concept, we shall be in trouble If difficulties arise, they will come from people—civilian and military—who do not wish to take literally what General Bradley says

So far as the Commission is concerned, the task of getting along with the military in the day-to-day relationships is fairly easy, although it is sometimes bothersome At the working level in the laboratories and in the field—where the technical military men rub shoulders with the Commission's scientists and engineers, where the man who is in training to pilot a bomber meets the man who invented the bomb—there is today, and there should always be, the closest possible relationship But in the process of getting the ore to feed the Commission's plants, in the operation of reactors to make plutonium, in the management of research laboratories to get the best possible results from the scientists and engineers, it is clear that the Commission can meet the schedules best and represent the American people best without military interference Once the tailor has taken the measurements for the suit and the cloth has been selected, he simply cannot take time out, if he is to get on with the job, to answer inquiries about the size of the needle, the strength of the thread, the bone from which the buttons come

Even where the military services have been unable to make up their minds precisely as to the characteristic of a

* Should We Fear the Military? by Gen Omar Bradley, *Look Magazine* March 11, 1952

certain type of weapon, the Commission's scientists, in the interest of saving time, have gone on with their inventing, improving, testing, and manufacturing, and the military services have almost invariably been pleased with the result The weapons steadily get better There are more of them and more varieties of them than ever before It is a record of which the Commission can be, and is, proud

But the relationship between the military and the atom is much broader than the day-to day conferences between the military services and the Commission concerning the characteristics and performance of weapons The broader question has to do with how the civilian elements in our government, both executive and legislative, can adequately appraise the total national security picture—of which atomic energy is a key part—and how they can analyze the assumptions behind military planning This is not a job for the Atomic Energy Commission alone, even in the field of atomic energy The Commission does not even have access to current war plans This is a task for the civilian heads of the Department of Defense, for the Bureau of the Budget, the National Security Council, the President, and the Congress

Within the executive branch of the government, the two agencies exercising the most responsibility in the field of national security are the Joint Chiefs of Staff, who originate recommendations for military planning and operations, on the one hand, and the National Security Council, the civilian review board, on the other A brief examination of the roles of these two will be instructive

Top military planning is the responsibility of the Joint Chiefs of Staff, which is composed of the Chief of each of the three services—the Army, the Navy, and the Air Force—plus a non-voting chairman One of their functions is to plan for the use of atomic weapons in the event of war The Chiefs today are rather isolated from the Atomic Energy Commission, and, for that matter, from most civilian

professional men such as scientists, businessmen, and those concerned with human relations. This would not be so bad if their planning were simply concerned with military maneuvers, but it isn't. Today, when so much of the Joint Chiefs' planning has to do with defense mobilization, and therefore intrudes into every segment of our economy, their isolation is unfortunate. Their role, as respects the Secretary of Defense, is also complicated by the fact that they report directly both to the President and the Secretary of Defense, rather than to the Secretary and through him to the civilian Commander in Chief.

The Commission frequently receives a Joint Chiefs' "requirement," as it is called, for a particular weapon or family of weapons, or a new reactor to produce a certain material, or a new production site, without any prior consultation between the Chiefs and the Commission. This is wrong. Proper liaison between the Commission and the Joint Chiefs is lacking. It is really not furnished by the Military Liaison Committee, which was set up in the Atomic Energy Act (as described in Chapter I) and which has as its membership two Army generals, two Air Force generals, two admirals, and a civilian chairman. This Committee was to function as the military watchdog of the newly created civilian Commission. What is needed today, however, is not watchdogging, but the unplugging of the channels of communication between the two agencies. Joint consultation at early stages could prevent many a *questionable "requirement" from being frozen at the Joint* Chiefs' level.

Until the respective roles of the Joint Chiefs, of the individual service Chiefs, of the civilian service Secretaries and the Secretary of Defense, are clearly defined and arranged into single channels of command, and until there is a mechanism for the injection of the civilian point of view into the planning of the Chiefs before it is crystallized, the

country must look to the National Security Council for comprehensive evaluation of the defense programs

The National Security Council is an agency little known to the average American, and yet there are many who believe that it is the most important agency of our government today Its function, according to the statute which created it in 1947, is "to advise the President of the United States with respect to the integration of domestic, foreign and military policies relating to the national security' Its membership consists of the President, the Vice President, the Secretary of State, the Secretary of Defense, and the Director for Mutual Security In addition, the Secretary of the Treasury and the Director of Defense Mobilization participate in the Council's activities on the invitation of the President The Chairman of the Joint Chiefs and the Director of the Central Intelligence Agency attend all meetings and are, by law—though not actually members—military and intelligence advisers to the Council

While the Chairman of the Atomic Energy Commission is not a member of the National Security Council, the President created in 1950 a Special Committee of the National Security Council, of which the AEC Chairman, the Secretary of State, and the Secretary of Defense are members The Committee was set up to advise the National Security Council The Council, in turn, advises the President on atomic energy matters affecting the three agencies As an example of its role, this Committee has attempted to analyze the large expansion programs in which the Commission has recently engaged It has been a useful committee, for it has provided at least some civilian control on important questions, rather than simply the appearance of civilian control But to achieve to the fullest the dual objective of civilian control and military readiness will require the best thinking of our best brains, the patience of Job, and the understanding of each civilian

and military segment of our government of the problems and responsibilities of the other segments

Perhaps it is in order to suggest that there are instances in our present program where some real progress in military-civilian co-operation has been achieved Take the Joint Task Forces, for example, which are established to conduct the weapons tests at Eniwetok These Task Forces are established jointly by the Department of Defense and the Atomic Energy Commission The two agencies agree, and they have always done so with no difficulty, on a Task Force commander He may be an Army general, or a Navy admiral, or an Air Force general Members of his staff are made up of civilians from the Commission and representatives of one or more of the services The responsibility for the various phases of the operation are divided into various compartments, and, here again, military men and civilian participants work shoulder to shoulder In several instances the civilian deputy commander of the Task Force has had officers of the three services reporting to him

As always, where men of competence are imbued with the importance of the mission, they somehow see to it that they work smoothly together There has been virtually no trace of interservice rivalry or conflict between the civilian and the military personnel in these Joint Task Force operations The operations are complicated and there could very readily be conflicts, but everyone seems anxious to get the job done and not to let jurisdictional conflicts interfere The Air Force contingent, which is responsible for, among other things, the aerial observation of the test, including cloud sampling by aircraft, must gear its work closely with the Navy ships engaged in supply operations and security patrol, and with the various contingents of the Army responsible for certain logistic and military phases of the operation Much the same thing applies at the Nevada test site, where the Test Director has always been a member of the staff of the Commission

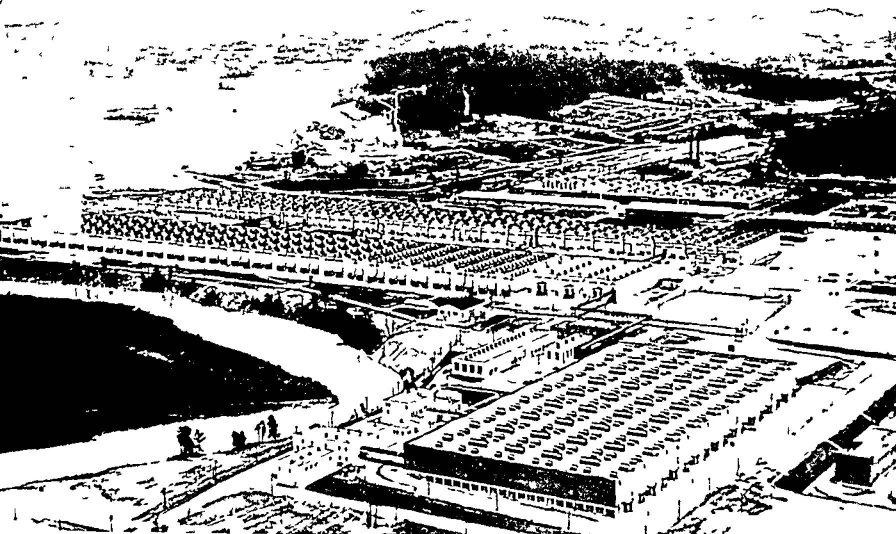
But the testing of weapons is an example of technical and administrative co-operation The main problem, and one with which every American should be concerned, is the lack of real co-operation—under the present system—between the military and civilian authorities of the government in the development of national defense policy What is needed is a basic rearrangement of the lines of command, the assignment of responsibility, and the mechanics of liaison Atomic energy is but one example of the inadequacy of the present arrangement There are others, and they are just as vitally connected with the general welfare of the nation If we are to continue to survive the strains and stresses of the cold war and the preparedness program, these fundamental faults in the present system must be corrected all along the line

CHAPTER *viii*

Power: The Peaceful Goal—First Phase

PROBABLY the most widely discussed subject in atomic energy, after "the bomb," is something we have come to call "atomic power." There is ample reason why this should be true, for of all the potential peaceful uses of the atom, the production of useful power is the one with the brightest promise of early, large-scale realization. It is important, therefore, that we understand exactly what we are talking about when we use the phrase "atomic power."

Although the terminology that has grown up in the still new field of atomic energy is subject to varying interpretations, the words "atomic power," when used in connection with the peaceful utilization of the atom, generally mean but one thing: heat. Most of the energy released in a controlled nuclear chain reaction appears in the form of heat, just as the energy in, say, a coal fire, which is a chemical chain reaction, also appears in this form. In other words, the phrase "atomic power" is used in much the same way as "coal power" or "oil power"; that is, the atom is the fuel and not something that is sent out over a transmission line. Atomic power is not, therefore, like electricity, although it can, like coal power, be used to produce electricity, just



Gaseous Diffusion Plant K 25 at Oak Ridge with Auxiliary Process Plant K 27 in foreground Built during World War II K 25 is the largest continuous process plant in the world under one roof (*Courtesy of Westcott Oak Ridge Tenn*)

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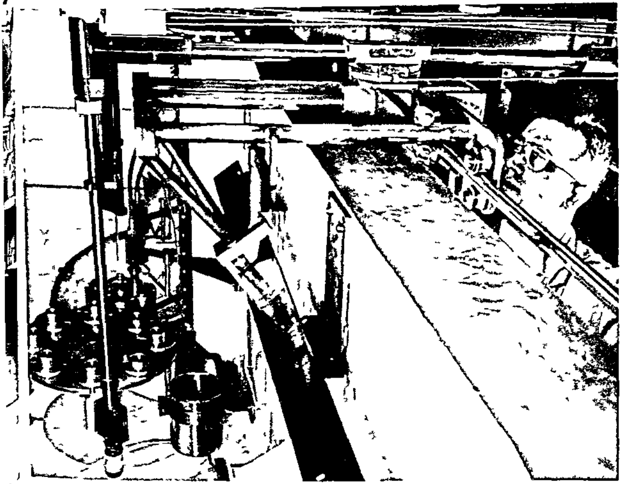
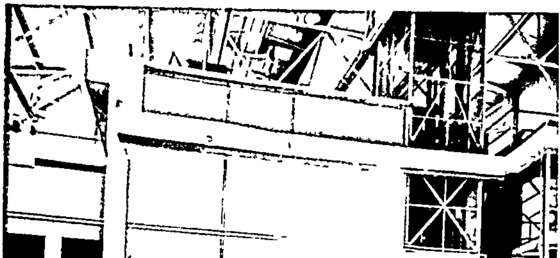
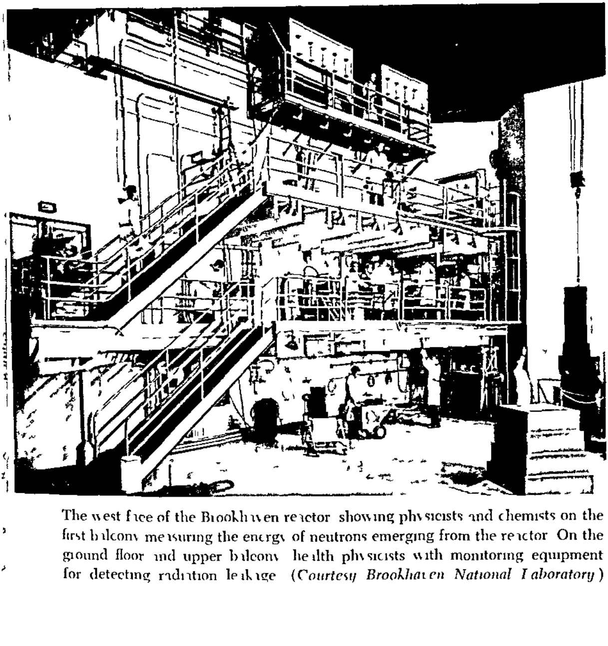


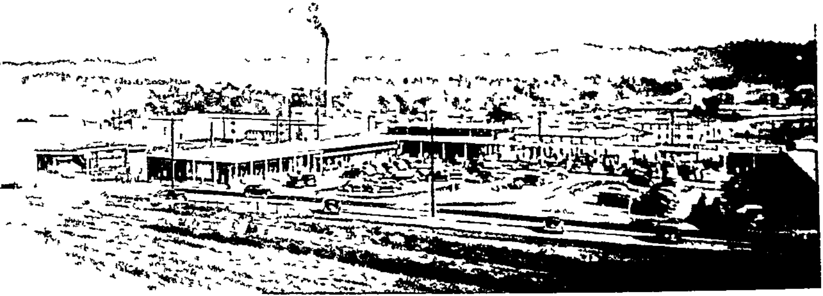
A radioisotope shipping bottle being handled mechanically by remote control at Oak Ridge (*Courtesy Oak Ridge National Laboratory*)



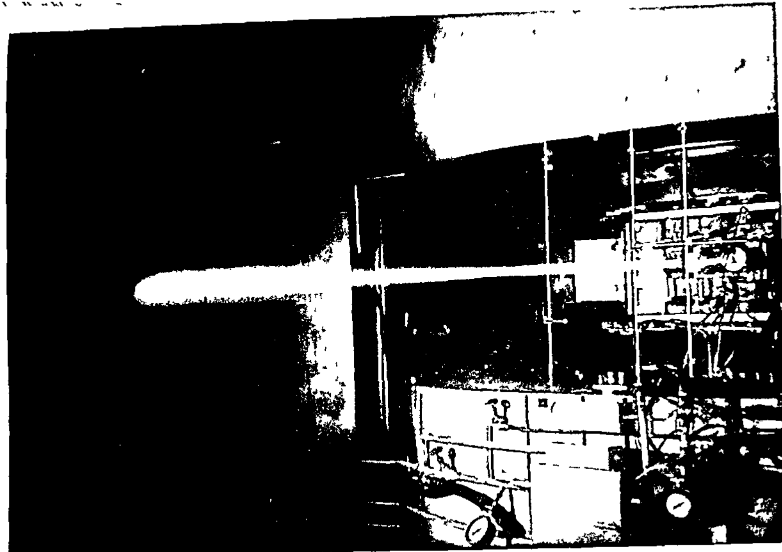
The Oak Ridge Pile which produces most of the radioisotopes used in this country. The substances to be irradiated are pushed in with a long rod through a carrier aligned with an opening in the pile. (*Courtesy Albert Fenn, Life Magazine*)



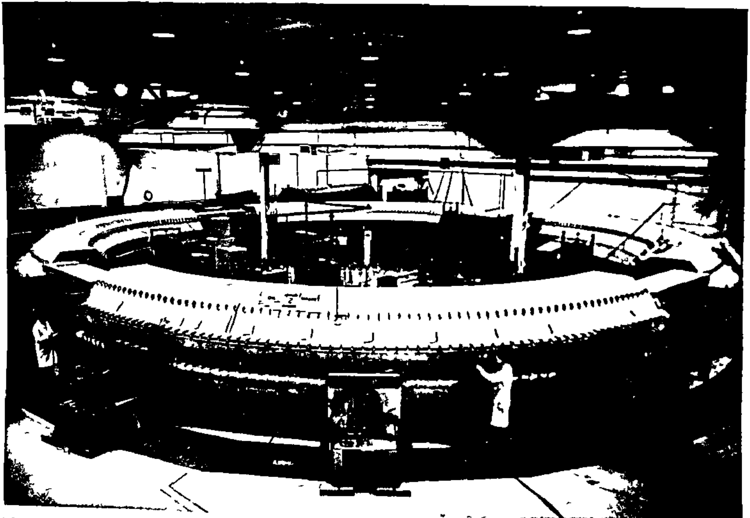
The west face of the Brookhaven reactor showing physicists and chemists on the first balcony measuring the energy of neutrons emerging from the reactor On the ground floor and upper balcony health physicists with monitoring equipment for detecting radiation leakage (*Courtesy Brookhaven National Laboratory*)



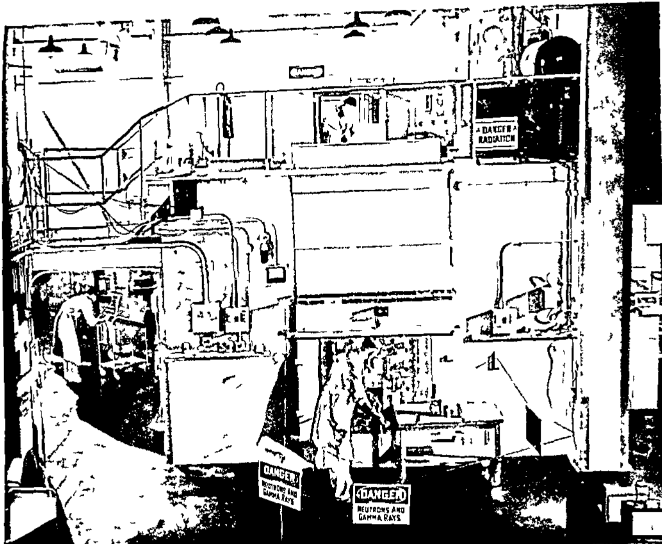
Part of the downtown section of Oak Ridge (U S Army *Photograph*)



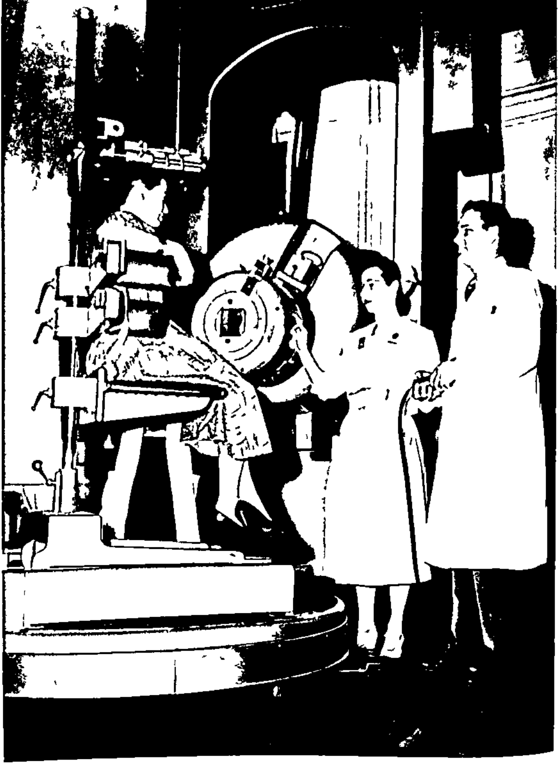
A beam of deuterons emerging from the acceleration chamber of the cyclotron at Argonne National Laboratory (*Courtesy Argonne National Laboratory*)



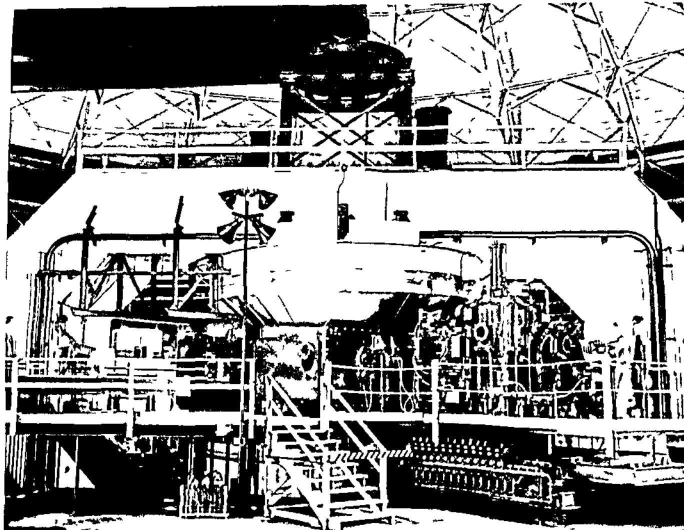
The Brookhaven cosmotron (*Courtesy Brookhaven National Laboratory*)



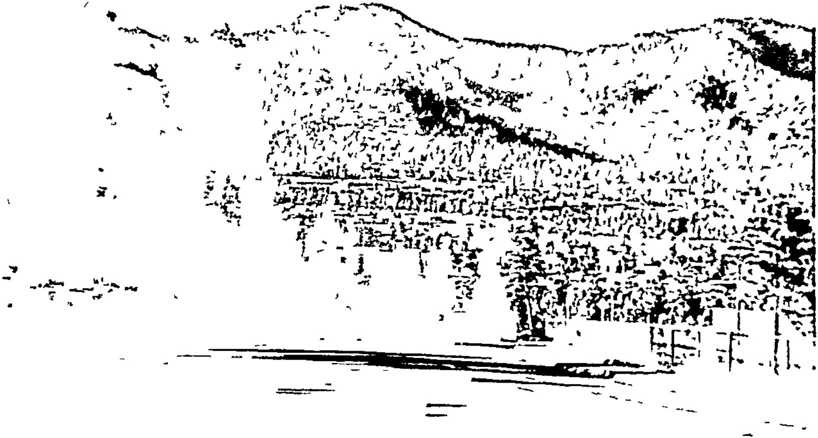
The Water Boiler Reactor at Los Alamos
(Courtesy United States Atomic Energy Commission)



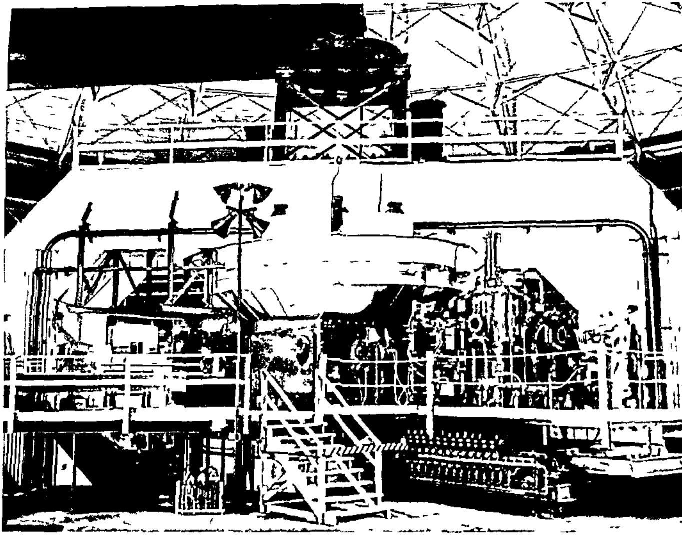
Demonstration of the use of a Van de Graaff generator in the treatment of cancer at Argonne Cancer Research Hospital. The patient is rotated under the X-ray beam. (*Courtesy Argonne National Laboratory*)



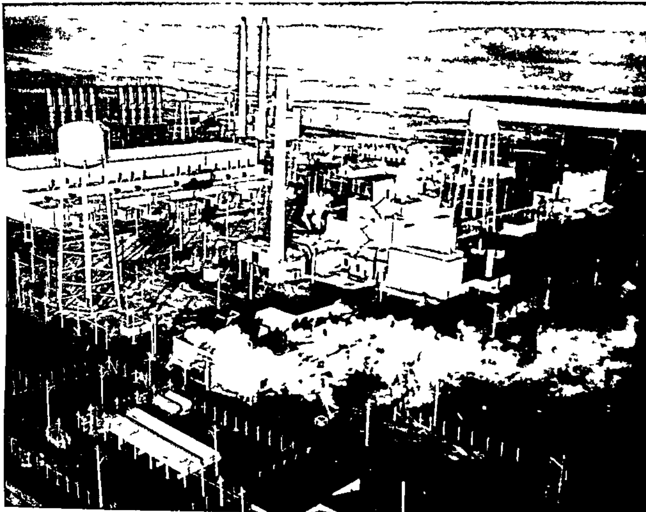
The 184 inch cyclotron at the University of California in Berkeley
(Courtesy University of California, Berkeley California)



A section of the Los Alamos residential area (*Courtesy United States Atomic Energy Commission*)

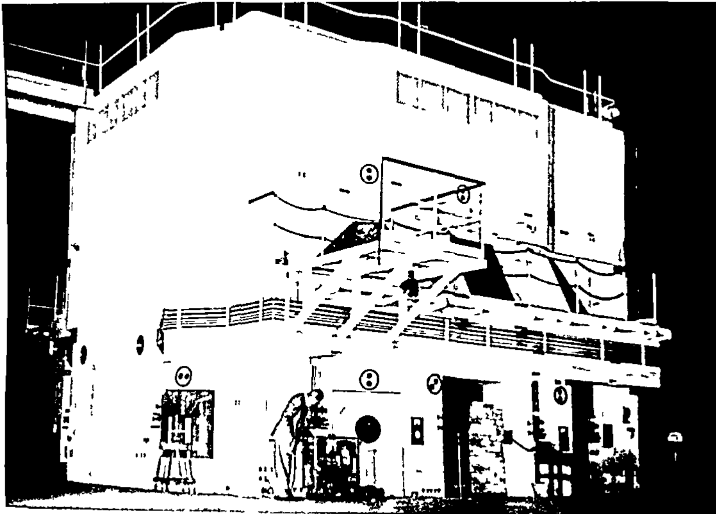


The 184 inch cyclotron at the University of California in Berkeley
(Courtesy University of California, Berkeley California.)

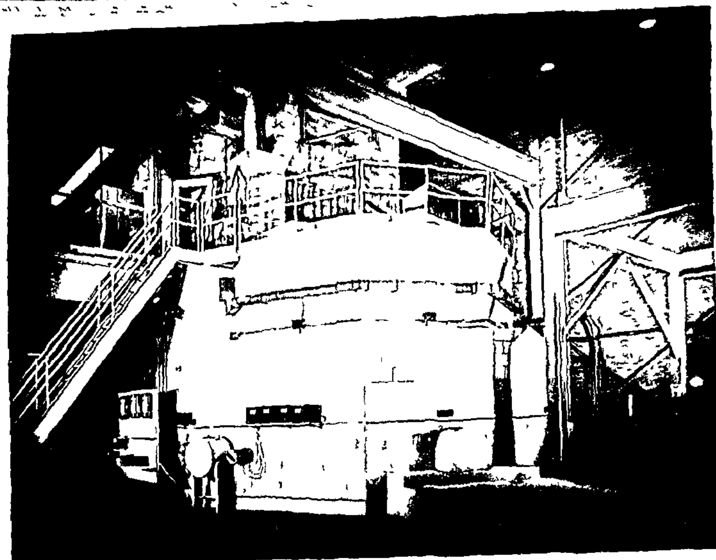


One of the main plutonium plants in the Hanford area at Richland
(*Courtesy Johnson Richland Washington*)

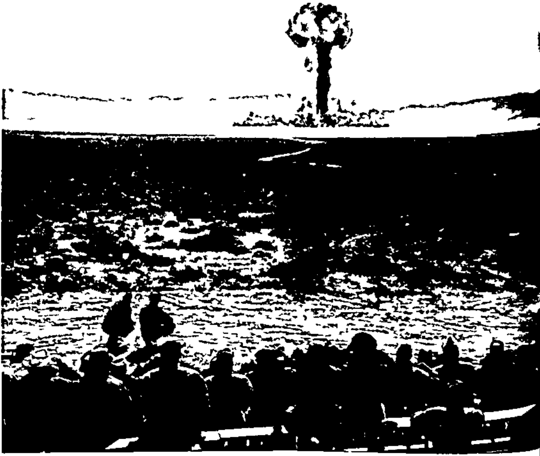
The Materials Testing Reactor shown here is but one of the facilities on the 400,000 acre National Reactor Testing Station in Idaho. The reactors are widely separated in the interest of safety. (*Courtesy United States Atomic Energy Commission.*)



Inside the Materials Testing Reactor building in Idaho
(*Courtesy United States Atomic Energy Commission.*)



The Experimental Breeder Reactor at the National Reactor Testing Station in Idaho. It produced power in 1951 and in 1952 demonstrated the feasibility of breeding. (*Courtesy United States Atomic Energy Commission.*)



How a Nevada weapons test looks to the official observers seven miles away. This is the explosion of an atomic artillery shell, Spring test, 1953

as it can be used to do most of the other things that large quantities of heat can do

In a sense, it would be entirely correct to describe a controlled nuclear chain reaction as a nuclear "fire" in which atomic "fuels" (called fissionable materials) are "burned" (fissioned) to produce heat for useful purposes As in the case of a chemical fire, "ashes" (called fission products) are left over after the nuclear fire has been extinguished

Although a nuclear fire resembles a chemical fire in that heat is produced and ashes remain, that is about the end of the similarity Furthermore, there are a number of striking differences

1 The quantity of heat produced per unit weight of fuel is vastly greater in a nuclear fire than in a chemical fire For example, one pound of the atomic fuel, uranium-235, if burned in a nuclear way, will release 2,600,000 times the amount of heat produced from burning a pound of coal This, of course, is the great appeal of atomic power, and the one single fact that makes the whole difficult game worth the candle

2 Whereas, for all practical purposes, a chemical fire can exist only in an atmosphere in which oxygen is present, a nuclear fire can exist only in an atmosphere made up of billions upon billions of the incredibly small, invisible atomic fragments called neutrons A nuclear fire, therefore, "feeds" on neutrons But neutrons not only cause atoms to fission, they themselves are produced by the fission process Thus a nuclear fire itself creates the means by which it is propagated The fire is controlled, therefore, by controlling the number of neutrons it has access to, much as one can control a coal fire by governing the amount of air available to it Neutrons are so important to atomic energy that some people call the program "the neutron business"

3 Whereas there are many materials on earth (coal,

wood, petroleum) that can be made to burn in a chemical way, there is only one naturally occurring substance that can be made to burn in a nuclear way This is the very rare variety of uranium known as "235," which constitutes but seven tenths of one per cent of the metal uranium as it is found in nature Fortunately for the future of atomic power, there are two other naturally occurring substances that can be made into atomic fuels uranium-238 and thorium, which can be changed into "inflammable" plutonium and uranium-233, respectively This can be done, interestingly enough, by exposing them over a period of time to a dense atmosphere of neutrons, such as that created by a nuclear chain reaction in uranium-235 Thus, a nuclear fire not only produces the means by which it is propagated, it also produces the means by which additional supplies of atomic fuel can be produced Uranium-238 and thorium are more than a hundred times as plentiful in nature as uranium-235, and together with "235" they constitute the fuels of the atomic age

4 A nuclear fire, unlike a chemical fire, is invisible In burning, it creates large amounts of invisible nuclear radiations, similar to X rays, which are dangerous to humans and damaging to certain types of materials For this reason, as we have seen, a nuclear fire must be surrounded by a thick shield of lead or concrete or water to seal in this dangerous radioactivity In addition, the ashes left over from a nuclear fire remain "hot" in a radioactive sense for very long periods of time and must therefore be handled with the utmost care

5 Unlike a chemical fire, a nuclear fire cannot be ignited until a certain minimum amount of fuel, called a "critical mass," has been assembled Below this amount, not enough neutrons are produced by fissioning atoms to make the fuel burn Above this amount, however, the fuel reacts spontaneously

It will be recalled from Chapter III that the devices in

which atomic fuels are burned are called nuclear reactors Since many people are accustomed to thinking of a nuclear reaction in terms of a fire, they are also frequently called 'atomic furnaces" Sometimes reactors are called "piles," because the first reactors to be built were literally piles of uranium and graphite

There are about as many kinds of nuclear reactors as there are coal, gas, and oil furnaces Some are compact, with fuel receptacles no bigger than a football, while others are as large as a house Some are operated at high power levels, some at low Some use high-grade fuel, some use low-grade The fuel of some is in the form of solid bars or rods, while others use fuel in the form of liquid solutions

The kind of reactor one chooses to build depends largely upon what one wishes to do with it If the objective is to produce a dense atmosphere of neutrons to change uranium-238 into plutonium, that is one thing, if the objective is to develop a compact, high-powered engine for a submarine, that is quite another But whatever kind of reactor one wishes to build, there are certain basic elements that must go into it if it is to be any more than a very low-powered research device

1 Fissionable fuel, whether it be high-grade or low-grade, liquid or solid

2 A shield to seal in the lethal radiations produced by the reaction This is usually lead or concrete, or both

3 A means of controlling the reaction, that is, a means of starting it, stopping it, and of keeping it at just the desired level while it is going on This is generally accomplished by means of rods made of some neutron-absorbing material such as cadmium The fire can be controlled by moving these rods in and out of the atomic furnace When they are pulled out, the reaction speeds up, when they are pushed all the way in, the reaction stops

4 A means of conducting away from the reactor the

heat that is produced by the reaction If this were not done, the reactor parts would melt, or, if exposed to air, ignite chemically Heat can be removed by circulating air, water, liquid metal, or gas through the reactor In an atomic power plant it is this heat that must be taken out and put to work One obvious way of utilizing the heat is to make steam which in turn can be used to perform such productive work as generating electricity or turning the screws of a ship

5 A means of slowing down the neutrons which feed the reaction Neutrons leave a splitting atom at speeds of thousands of miles per second, and most reactors use a material, known as a "moderator," to slow these neutrons down When a moderator is used, it is incorporated in the very heart of the reactor along with the fuel Some of the best of these decelerating materials are graphite, heavy water, and beryllium Ordinary water is also effective in some instances Whether a reactor needs a moderator or not depends upon the purity of its fuel If normal uranium (less than one-per-cent fissionable material) is used, a moderator is always required If enriched uranium (in which the proportion of fissionable U-235 has been increased) is used, less moderator is required If pure fissionable material is used, no moderator is required *

I have heard some people say, upon having a reactor described to them 'If that is all there is to this atomic power business, why don't we just build ourselves some of these atomic furnaces, stoke them up good with atomic fuel, throw in a pailful or two of heavy water, and let them go to work for us?"

This is, of course, an obvious question, but it implies

* As these statements suggest the relative absorption of slow neutrons by U 235 is large as compared with their absorption by non fissionable material Fast neutrons, on the other hand are absorbed about equally by both Thus where both fissionable and non fissionable materials are present in the fuel fast neutrons cannot be used because too many of them will be absorbed in the non fissionable material and the fission chain reaction will not sustain itself

that everything is a little simpler than is actually the case, and it ignores the immense differences between power *per se*, usable power, and economically feasible power.

Every reactor that has ever been built has produced some power in the form of heat. The world's first reactor, the uranium and graphite pile built by Enrico Fermi in Chicago in 1942, reached a top power level of about two hundred watts of heat energy (enough to light two average-sized lamps) for a very short period of time. It could not be allowed to go any higher, however, and it could not even stay at this low level for very long, because it had no cooling system and no shield. It was really nothing more nor less than a carefully designed experiment to prove conclusively that a nuclear chain reaction could be made to work. To have operated the pile at a higher power level would have meant running the risk of melting the parts or of injuring the people engaged in the experiment. Two hundred watts was not much power, but it was some, and it was real. It could not in any sense be called usable power, however, because there was no way to take it out of the reactor and put it to work.

Since construction of the first pile at Chicago in 1942, the Manhattan Engineer District and the Atomic Energy Commission have built more than a score of research and development reactors, mock-ups, and test assemblies, as well as a number of reactors designed for the sole purpose of producing plutonium. To gain a feeling for the trend of reactor development over the past ten years, it might be profitable to run down a list of the projects that have played, or are now playing, a key role in its advancement.

1. *CP-2*

Built in 1943, this reactor was a replacement for Fermi's first pile, which was dismantled after its successful operation. The designation "CP-2" stands for 'Chicago Pile Number Two.' Like the first pile, CP-2 uses normal, natu-

ral uranium as fuel, and graphite as the agent for slowing down neutrons Of somewhat higher power level than the original CP-1 (2,000 watts instead of 200), CP-2 has a shield of lead and concrete to seal in the nuclear radiation it generates Because the 2,000-watt power level is so low, not enough heat is generated to require a cooling system, and none is used CP-2 is still operating on its original fuel supply at the Argonne National Laboratory at Chicago It is used for research purposes

2 *Oak Ridge Graphite Reactor*

This pile, the world's third, was built at Oak Ridge in 1943 Like the first two, it uses natural uranium fuel, and graphite as the neutron moderator The pile was built as a pilot plant for the plutonium-producing reactors at Hanford It is still in operation as a research and training facility and is the source of most of the radioisotopes now being sold by the Atomic Energy Commission It is of much higher power level than CP-1 and CP-2, and therefore requires both a cooling system and a thick shield of lead and concrete The power level is about 2,000 kilowatts (2,000,000 watts), and circulating air is used as the cooling agent The reactor does not warm the cooling air to a sufficiently high temperature, however, to make possible the production of useful power, even for experimental purposes

3 *Hanford Research Reactor*

Very similar to CP-2, this reactor was placed in operation in February 1944 to test materials being used in the construction of the first plutonium-production piles at Hanford It operates at practically zero power 10 watts

4 *Hanford Production Reactors*

The first of these went into service in 1944 The Hanford reactors have been designed for just one purpose to produce neutrons from U-235 for changing uranium-238 into plutonium for bombs They are fueled with natural uranium, which contains both the uranium-235 fuel and the uranium-238 that is needed, and they run on neutrons

slowed down by graphite The reactors are several stories high and contain thousands of blocks of graphite and thousands of cylinders of uranium (called "slugs") which are removed after months of nuclear cooking so that the newly created plutonium can be extracted The reactors are cooled by purified water from the nearby Columbia River So much heat is generated that a good part of the Columbia must be pumped through them, and the temperature of the river below the Hanford plant is raised by a measurable amount Not only is power wasted in this way, but power must also be used to pump the water through the reactors It is therefore a doubly wasteful process

The trouble with the Hanford reactors, so far as power production is concerned, is that the heat produced in them is measured more in terms of quantity than of temperature, and high temperature is really what is needed if steam is to be made and useful power is to be produced efficiently The reactors could no doubt be rigged up to produce some usable power, but studies have shown that it would be extremely expensive compared with other power available in the Northwest Furthermore, power production would interfere with the manufacture of plutonium, something we could not afford when the reactors were built, and still cannot afford

5 *CP-3*

This, the third reactor to be built at Chicago, was completed in May 1944 It is noteworthy in that it was the first reactor in the world to use heavy water in place of graphite as a neutron moderator It was built for research purposes and to gain experience in the use of this new moderating medium The fuel is in the form of solid bars of uranium suspended in a tank containing the heavy water At first CP-3 used normal, natural uranium as fuel, but in 1950 this was replaced with uranium metal in which the percentage of U-235 present had been increased from 0 7 per cent to 15 per cent CP-3 has a power level of 300

ral uranium as fuel, and graphite as the agent for slowing down neutrons Of somewhat higher power level than the original CP-1 (2,000 watts instead of 200), CP-2 has a shield of lead and concrete to seal in the nuclear radiation it generates Because the 2,000-watt power level is so low, not enough heat is generated to require a cooling system, and none is used CP-2 is still operating on its original fuel supply at the Argonne National Laboratory at Chicago It is used for research purposes

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lar to the Oak Ridge Graphite Reactor, except that it is larger and operates at a much higher power level 30,000 kilowatts It uses natural uranium as fuel and graphite as the neutron moderator The shield is of iron and concrete, and the cooling agent is air This was the first research reactor to produce enough heat at a sufficiently high temperature to permit the generation of some usable power, but it has never been used for this purpose The cooling air leaves the reactor at a temperature of 330° F hot enough to operate a small steam power plant, but not hot enough to operate it efficiently Although a power demonstration with this reactor has long been recognized as possible, the negligible research gain that would be made by attaching a power plant has never been considered worth the cost it would entail in money and interference with other research work

9 *"Swimming Pool"*

This reactor was completed at Oak Ridge in 1951 It is a very low-power reactor (10 kilowatts) used in shielding experiments Its most distinguishing characteristic is that it is suspended in a pool of water twenty feet deep which serves as both cooling agent and shield

10 *Experimental Breeder Reactor (EBR)*

Completed in 1951 at the Atomic Energy Commission's Reactor Testing Station in Idaho, this was the first reactor in the world to produce power to generate electricity Although the electricity has been used to light the laboratory and operate its equipment, including the pumps that circulate the cooling agent through the reactor, the power production experiment is subsidiary to the main purpose of the reactor and is carried on for research purposes only The main purpose of the EBR is to investigate the process known as "breeding" It will be recalled that the neutrons produced by a nuclear fire can be used to change U-238 into plutonium and thorium into U-233 The idea of breeding is to do this so efficiently that more fuel is cre-

kilowatts, and is cooled by circulating the heavy-water moderator through a heat exchanger

6 *"Water Boiler"*

This reactor, located at Los Alamos, was also completed in May 1944 It was the first reactor to use fuel in a liquid solution, and also the first to use enriched, or moderately high-grade, uranium in place of natural uranium The fuel contained 15 per cent U-235 instead of the normal 0 7 per cent, and was originally in the form of a uranium compound (uranyl sulphate, later uranyl nitrate) mixed with water—a concoction the scientists call "soup" As this liquid solution becomes hot, it will simmer or boil, whence the reactor's name The Water Boiler, which was used in research studies leading to the atomic bomb, was first operated at a power level of about 1/20th of a watt, but this has since been raised to 45 kilowatts The reactor, which is still operating, is cooled by water flowing through coils that wind through the stainless steel "pot" containing the reacting solution

7 *"Clementine"*

This reactor, which was in service at Los Alamos from 1946 to 1953, could claim three important distinctions It was the world's first reactor to use pure fissionable material as fuel, the first to be constructed without the use of a moderator, and the first to use liquid metal as the cooling agent Because it had no moderator it operated on fast neutrons, and for this reason was known as a "fast reactor" Its fuel was pure plutonium Clementine got its interesting name from the fact that plutonium bore the code designation '49' during the war, and 'Clementine" is a song about 'forty-niners ' Clementine was cooled by circulating liquid mercury and operated at the relatively low power level of 25 kilowatts

8 *Brookhaven Reactor*

This reactor, completed in 1950 as a research facility for the Brookhaven National Laboratory, is generally simi-

is to test the feasibility of using fuel, moderator, and cooling agent in a homogeneous liquid mixture Just as the EBR in many ways is a higher-powered model of the fast Clementine reactor at Los Alamos, so the HRE is a higher-powered model of the Los Alamos Water Boiler The power it produces is enough to supply electricity to about fifty homes, but, like the EBR, it would be expensive electricity The reactor itself cost $1,000,000 and it took about $3,000,000 to develop it

13 *CP-5*

This is a reactor recently built at the Argonne National Laboratory to replace the original heavy-water reactor, CP-3, which will have to be dismantled because it is situated on land which the government has a contractual obligation to vacate It will serve as a research and development unit Of considerably improved design, it will use enriched uranium fuel and heavy water as both the moderator and cooling agent It will not operate at sufficiently high temperature to produce power efficiently, but it should add to our knowledge of heavy-water reactors as possible producers of useful power

14 *Submarine Thermal Reactor* (*STR*)

This is the land-based prototype of the engine that will go into the first atomic-powered submarine, the U S S *Nautilus*, now being built at Groton, Connecticut The prototype, which recently began operating, is located at the Atomic Energy Commission's Testing Station in Idaho The first seagoing model is under construction by the Westinghouse Corporation at the Commission's laboratory in Pittsburgh, and it is not too far behind the prototype For fuel, the STR uses uranium enriched in U-235 in the form of solid pieces of metal submerged in a tank of highly purified ordinary water that serves as both cooling agent and moderator The heat produced by the reactor will be taken out by circulating water to a boiler where steam will be produced to operate a turbine to power the submarine

ated than is consumed in the process—a potential means of changing all the minable uranium and thorium in the world into fissionable fuel The Commission announced in June 1953 that breeding had been achieved in the EBR.

The EBR is similar to Los Alamos' Clementine in that it is fueled with pure fissionable material, has no moderator, and uses liquid metal to remove the heat produced It differs, however, in that it is many times more powerful, its fuel is uranium-235 instead of plutonium (although it is expected ultimately to run on plutonium just as well), and its cooling agents are potassium and sodium in place of mercury These liquid metals leave the EBR at a temperature of 662° F, high enough to make steam efficiently The steam operates a turbine that in turn drives an electric generator with a capacity of 250 kilowatts, or enough to supply several blocks of modern homes In case you would like one on your street, however, I think you should know that the EBR cost nearly $3,000,000, exclusive of the cost of fuel This is an example of usable power, but it is a far cry from economically feasible power

11 *Materials Testing Reactor (MTR)*

This reactor, also located in Idaho, was completed in 1952 It was built to test the effect of intense nuclear radiation on reactor construction materials The fuel it uses is "enriched," or moderately high-grade, uranium, and ordinary water freed of impurities serves as both the moderator and cooling agent The MTR normally operates on slow neutrons A pilot model of the MTR, called the Low Intensity Testing Reactor, was built at Oak Ridge in 1950 and is still in operation

12 *Homogeneous Reactor Experiment (HRE)*

Completed at Oak Ridge in 1952, this reactor early this year became the second known reactor in the world to produce useful electric power As in the case of the EBR, however, the power experiment is for research purposes only and is subsidiary to the reactor s main purpose, which

16 *Submarine Intermediate Reactor (SIR)*

The prototype of this reactor is being constructed at the Knolls Atomic Power Laboratory at Schenectady, New York It is being built for the same purpose as the Submarine Thermal Reactor, although it was started somewhat later and will differ from it in several important ways It is particularly interesting in that it will be the first reactor to use neutrons of intermediate speeds The speed of the neutrons will be controlled by a new moderating material the light metallic element beryllium The hope is that neutrons in the intermediate velocity range will permit the reactor to run for longer periods of time without the need to refuel The Intermediate Reactor will use enriched uranium fuel and will be cooled by liquid sodium All in all, it will be a very advanced reactor, but, like the STR, the power it produces will be feasible from a dollar point of view only for national security purposes

17 *Aircraft Reactor*

The achievement of atomic-powered flight is one of the longest-range projects now being worked on in the field of atomic energy It is also one of the most difficult and expensive Work is nevertheless under way to develop an atomic aircraft engine for the Air Force, and a test facility is now under construction at the Commission's Reactor Testing Station in Idaho The great appeal of the aircraft reactor, and the characteristic that makes it well worth working toward, is the almost unlimited range it promises to give our military aircraft One might think in terms of several trips around the globe without the necessity of refueling But there are a host of problems not encountered in other atomic power applications, and a major one is to design a shield that is light enough to be taken aloft and will at the same time protect the crew from dangerous radioactivity Shielding usually means lead, and lead is very heavy, and obviously in an airplane weight must be held to a minimum These problems will be solved, however,

as well as a turbo generator to produce electricity The word "thermal" in the reactor's name means that the neutrons feeding the reaction will be slowed down to "thermal" or very slow speeds

The STR is of considerable historical significance, for it will be the first practical utilization of atomic power It will be useful power in a very real sense It will not be economically feasible power, but in matters having to do with the national security, economic feasibility is not the controlling factor The controlling factor is, instead, military value, and the military value of the atomic submarine will be its ability to travel entirely submerged for thousands of miles The power plant of a normal submarine, while it is operating under water, is its storage batteries An orthodox submarine can therefore travel under water at high speed for only a very short period before its batteries need recharging To recharge, the submarine must use its diesel engines, and, to use its diesels, which require oxygen and produce an exhaust, it must surface When it is on the surface, it is not only a target, it is also no longer a submarine With an atomic engine, however, which requires no oxygen and which can operate for very long periods of time under water without refueling or recharging, the vessel remains a submarine virtually all of the time, with its range limited only by the endurance of the crew

15 *Savannah River Production Reactors*

Like the Hanford Production Reactors, these are not designed to produce usable power They are being built, instead, to produce materials for use in either A-bombs or H-bombs They will nevertheless produce heat in large quantities, and will thus help reactor scientists to learn more about building reactors for the production of usable power Whereas the Hanford reactors use graphite as a moderator, these will use heavy water The work at Chicago on CP-3 and CP-5 was basic to the design of the new reactors at Savannah River

some cases it amounted to no more than one tenth of a watt But not one of them produced anything that by the wildest stretch of the imagination could be called usable power

Then, in 1951 and 1953, there came two reactors, the EBR in Idaho and the HRE at Oak Ridge, that actually produced some usable power in experimental quantities And now, except for the bomb-material reactors at the Savannah River plant, the Commission's reactor development program is mainly pointed in the direction of developing reactors to produce power for a practical military purpose propulsion of submarines, aircraft, and ships We have progressed, therefore, from the purely research phase, through the usable-power-for-experimental-purposes phase, to the usable-power-for-practical-purposes phase But we have yet to enter the phase where atomic power becomes economically feasible, that is, where the atom produces usable power for a practical purpose at a price that can compete with power from coal, oil, or gas

There is likely to be some difficulty, as a matter of fact, in recognizing when economically feasible atomic power is actually here Obviously what is economically feasible or competitive in one part of the world is not necessarily competitive in another In some regions, such as the remote areas of Africa, the South Pacific, or the Arctic, electric power may cost as much as three cents per kilowatt hour to produce In certain other places, even in our own western United States, power may cost from ten mills to two cents per kilowatt hour to produce Even in a city such as Chicago production costs may amount to six or seven mills per kilowatt hour, and yet in other places, such as the Pacific Northwest, where falling water is plentiful, be as low as 2 5 mills

What, then, is really meant by the phrase "economically feasible power"? If we were to take the Arctic as an example, it might mean something that was terrifically ex-

and we shall someday see an airplane powered by a reactor But this will undoubtedly be several years after the shakedown cruise of the first submarine, and it will cost considerably more money

18 *Large Ship Reactor*

Military interest in nuclear power stems from the high concentration of the fuel and the "cleanness" of the heat-producing reaction If large surface ships could be powered with atomic energy, their range could be enormously increased, and the problems of air intake and uptake, stacks and stack gases, and procurement and handling of bulky, inflammable fuels could be eliminated The Commission therefore has had an active program for the development of a reactor to power a large ship, such as an aircraft carrier Of all the reactors that have been built or are now under active development, the Large Ship Reactor will come closest to what will be needed not only in commercial shipping, but also in large, central-station electric power plants This is true, of course, because of the great quantities of heat that will be produced at high temperatures In this reactor heat will be used to make steam to power the ship's turbine Development work on the Large Ship Reactor has only recently begun, but, if sufficient financial support is forthcoming, progress can be made at a steady rate

A review of this list of noteworthy reactor projects reveals the trend of reactor development over the past decade The first reactors were built for the sole purpose of finding out whether or not a nuclear chain reaction could be made to work Then came scaled-up versions of these first models designed and built under a high-priority program to produce plutonium as rapidly as possible for bombs Then came experimentation with various new types built for the purpose of adding to man's knowledge of basic reactor-design principles and nuclear physics

All of these reactors produced power, even though in

CHAPTER *ix*

Power · The Peaceful Goal— Second Phase

We are today in the beginnings of a period of intensive and exciting development work in the field of power reactors, but it is questionable whether the best results can be achieved if the first power reactors are put down in isolated, high-cost areas remote from existing laboratories and scientists The first reactor designed specifically for civilian power purposes would very logically be a pilot, rather than a full-scale, plant And if it is to play the most useful role possible as a pilot plant, its location should be governed not by the cost of competitive fuels but by the availability of existing talent in the reactor field—that is, the men who will design it, build it, operate it, and learn from it And if this is true, it will have to be primarily a developmental rather than a commercial device

Since reactors are still in the developmental stage, they are not only more expensive than they will be later on, but are also less efficient and less reliable You can use a costly and inefficient plant in a submarine, where the expense is outweighed by the military advantage you gain (the STR prototype in Idaho cost $20,000,000, exclusive of fuel—an expensive engine for a submarine), but the operator of an

pensive by New York or Pittsburgh standards, and yet, for the Arctic, much cheaper than the cost of hauling in heavy shipments of coal or oil to fuel an orthodox power plant In short, therefore, when we speak of economic feasibility, we are speaking of relative, and not absolute, costs, a fact which suggests that the first reactor to produce usable power for a practical civilian purpose should be located in an area where normal fuel costs are high There are some, in fact, who say that there are places in the world, and even this country, where it would be feasible to do this now, today

This might be true, but there are several drawbacks to such an approach in the year 1953 Inasmuch as a stationary reactor designed solely to produce power for a practical purpose has never been built, the scientists are not at all sure of the best design or the most economical size A small reactor producing 10,000 kilowatts of electric energy might be built today for $10,000,000 and produce electricity at fifty mills per kilowatt hour But a reactor costing only six times as much might be expected to produce twenty-five times as much electric energy at eight mills per kilowatt hour

No one, of course, knows any of these things for certain, for the simple reason that no real atomic power plant has yet been built and operated Many of our cost calculations will depend to a large extent upon what we learn in the immediate future about the construction of power reactors But units of the size described, and at the cost indicated, appear to be feasible and will probably produce power at approximately the prices quoted

tion-resistant systems that employ such novel heat-transfer agents as liquid sodium One thing that is worth remembering about these systems is that when they are built they are built once and for all There is no climbing in and out of the ducts and pipes to fix up leaks and breaks, unless you are willing to risk getting a lethal dose of radioactivity In connection with this heat-transfer problem, it is interesting to note that when the Homogeneous Experiment at Oak Ridge produced its first electric power, the electric generator turned out 150 kilowatts although the reactor was operating at 1,000 kilowatts This is but 15-per-cent efficiency, compared with the 30 per cent or more of the average coal-burning power plant

But these problems too will be solved—and, as a matter of fact, are being solved—in the effort to produce reactors to do a propulsion job for the military A good share of the design, development, and research work going into these military reactor programs will bear real fruit when we sharpen up our pencils, as people are beginning to do today, and figure the cost of reactors which would do a job for civilian industry The submarine, aircraft, and large ship reactor programs are spawning a myriad novel alloys and ceramics, designs and techniques that would not have seen the light of day for many years had there been no strong incentive to build power reactors where cost was not of primary importance

The situation today in atomic power is not vastly different from the situation in the oil industry when the first diesel engine went into a submarine The diesel, like the reactor, served its first practical purpose in a submarine As a matter of fact, it made the submarine possible, for there was no place for a steam plant in an undersea craft But this first diesel was not in the least bit an economically feasible proposition There wasn't a railway or a trucking concern in the world that would have bought the first diesel engine Instead, the commercial companies

electric generating plant or a commercial freighter wants the most inexpensive, efficient, and reliable source of heat he can find

A commercial power plant, to be economically feasible, must not only cost a reasonable figure to build, it must also operate at very high temperature levels for very long periods of time without costly repairs, shutdowns, or replacements, and it must convert large quantities of heat efficiently into usable power

The problem of gaining very high temperatures and holding them for long periods of time is a particularly bothersome and expensive one It mainly involves finding and producing quantities of materials that can withstand both high temperatures and extremely high levels of nuclear radiation As an added difficulty, the materials must not absorb the neutrons that feed the reaction Unfortunately, there are not many materials that meet these rigid specifications, and to find and produce them in quantity requires a good deal of time and money For one thing, the search for new materials required construction of the $18,000,000 Materials Testing Reactor in Idaho Another example of the cost involved in this materials problem is the metal zirconium Zirconium, which was first produced in pure form by the atomic energy project from the same material as the soft, diamondlike stone, the zircon, is an excellent reactor construction material, meeting all the rigid specifications But the first zirconium produced cost $300 a pound—dollars that in all fairness should be charged up to the first reactor using the material Zirconium now costs but $15 per pound and the price is still falling—a good example of why the price of a reactor may be expected to drop substantially as the technology advances

The problem of extracting usable power efficiently from the heat produced in a reactor is also a difficult and challenging one, involving airtight, corrosion-resistant, radia-

goal is in sight The principle of atomic power has been proved, all that remains is to cut the costs

This raises some questions Most of all, it raises the question whether or not the government monopoly should be relaxed to let in private enterprise and gain the advantages of free competition, or at least a reasonable facsimile of free competition There is a lot that can be said for competition when the objective is mainly one of reducing costs It is the principle upon which the United States has always relied when the goal was to achieve greater economy and efficiency, and it has always paid off

As a result of government dominance during and since the war, reactors have been developed for the most part only by people attached, at one time or another, to the programs of the Manhattan Engineer District or the Atomic Energy Commission With few exceptions, knowledge and experience in the reactor field are concentrated in such concerns as General Electric, Westinghouse, Union Carbide, and duPont which, whatever their motives, whether patriotic or selfish or both, secured a 'foot within the door" by undertaking reactor development contracts with the government

There are many other concerns, however, which have valuable ideas, industrial know-how, and talent to contribute to this fast-growing technology, and it is noteworthy commentary on the progress that has been made that many of them have approached the Commission and asked for a chance to share in the knowledge that has been developed One way by which they have been given an opportunity to do this is through admittance to the Commission's School of Reactor Technology, operated at Oak Ridge by the Institute of Nuclear Studies Of the 268 people who have attended one of the four one-year courses so far offered by the school, 82 have come from industry

The most significant development to date, however, occurred in 1951 In that year the Commission, largely

waited until diesels had been improved to the point where they were reasonably efficient, until they could be bought at a reasonable price off an assembly line, until fuel processing and distribution costs had been stabilized, and until the diesel had proved itself to be a reliable and long-lived source of power Then, and not until then, did the diesel go to work in the commercial market So will it be with the reactor

Until now, virtually all research and development in the field of reactors has been done by the government It is quite true that the government has carried on its work through the medium of contracts with private industrial concerns and educational institutions, but the fact still remains that the work has been done at government instigation, at government expense, and, for the most part, in facilities owned by the government

This is not surprising, for several reasons First, under the Atomic Energy Act of 1946, the government has exclusive right to own fissionable materials, to own all reactors other than low-power research devices, to control all atomic energy information that isn't freely publishable, and to own all patents relating to the production and utilization of fissionable materials There isn't much room here for anyone but the government

Another reason why government dominance *is not surprising* is the fact that the market for reactors has, up to now, been purely a government one It is the government, not private industry, that is in the market for reactors to produce weapons materials such as plutonium, and to propel submarines, naval vessels, and bombers Moreover, up to now we have been in a phase in reactor development where the costs have been terrifically high, and where the payoff has been over the horizon

But all this is changing In racing parlance, it might be said that we have rounded the usable power turn and are headed into the economically feasible power stretch The

enter the atomic energy field and thus introduce real competition, the government must be prepared to create an atmosphere conducive to its entry on a "risk" basis This, of course, would mean a relaxation of the government monopoly, which in turn would mean at least some modification of the atomic energy law

The ultimate need for a change in the law had not escaped the Congress when it passed the Atomic Energy Act back in 1946 At that time the Congress had very wisely assumed that a day would come when economically feasible power could be produced from the atom It therefore provided in the law that, when that day arrived, the Atomic Energy Commission should report this significant event to the President, who in turn should report it to the Congress, so that the Congress might prepare for the new era with appropriate legislation All this was considered to be necessary because, under the terms of the present law, the Commission would automatically own and control any atomic power industry that might evolve out of research with reactors The Congress therefore wanted an opportunity to review and possibly change this arrangement when the time arrived for an atomic power industry to be born

The law, however, seemed to contemplate that such a time might arrive all at once, like a new and revolutionary discovery of science or the arrival of a comet from outer space In Section 7(b) of the Atomic Energy Act of 1946, this is what the Congress said

"Whenever in its opinion, any industrial, commercial or other non-military use of fissionable material or atomic energy has been sufficiently developed to be of practical value, the Commission shall prepare a report to the President stating all the facts with respect to such use, the Commission's estimate of the social, political, economic and international effects of such use, and the Commission's recommendations for necessary or desirable supple-

through the prodding of Charles Thomas of the Monsanto Chemical Company, instituted a program whereby industrial concerns hitherto excluded from the reactor development because of the government monopoly, could get a real chance to learn Under this arrangement, representatives of eight concerns were paired off into four groups (called "Industrial Study Groups") They were then cleared for access to secret information and given entree to the Commission's plants and laboratories to study at first hand the status of reactor development, with a view to evaluating the extent of their own real interest in the field and to developing specific proposals for direct active participation Because reactors understandably excite the special interest of utilities and companies engaged in chemical engineering work, three of the four study groups were composed of one company from each of these two categories These were Monsanto (chemical) and Union Electric (utility), Dow (chemical) and Detroit-Edison (utility), Bechtel (chemical engineering and construction, and Pacific Gas and Electric (utility) The fourth group was composed of Commonwealth-Edison and Northern Illinois Electric, both utilities In 1952 a fifth group, composed of Foster Wheeler (construction) and Pioneer Service and Engineering (chemical engineering) joined the study program

In the summer of 1952, following a full year of intensive study of the Commission's reactor program, the first four of the industrial study groups submitted their reports The reports included proposals to the Commission for further study leading to specific goals, and descriptions of the types of reactors the participating companies thought would best aid development and best help to provide an answer to the question of economically feasible power The designs and specific steps differed among the four groups, but it is significant, I think, that none was pessimistic All agreed, however, that if private capital is to

that will stimulate cost-cutting on a competitive basis and yet not be crystallized to the extent that our hands will be tied later on What is needed, more than anything, is the creation of a climate, both technical and legal, in which economically feasible power from the atom can be realized

In this period of questions—questions about cost, about location, about design, about materials—probably the most important of all from the policy point of view is "Who should do what?" On the one hand we have the government, which has so far done virtually everything, and on the other we have private enterprise, which has done virtually nothing except under contract to the government I think this situation must change I think it must change because until now we have been dealing in reactors designed to serve a government purpose, whereas from this point forward we shall be dealing in reactors designed to find a useful place in the national and world economies Private enterprise, therefore, must be permitted to enter the picture, not only because of the contribution that free competition can make to technological advancement, cost-cutting, and imaginative new applications, but also because it is only in a free market that the atom can ever demonstrate beyond doubt that it is economically feasible

Private enterprise must also be brought in because, if it isn t, the rate of technological advancement will be determined largely by the amount of money available from a dollar-conscious, but not always progress-conscious, Congress Also, if private enterprise is excluded during the forthcoming final development phase, the atomic power industry, when it is ultimately born, may very likely wind up as a government monopoly owned and managed by the Atomic Energy Commission or some other federal agency This would mean that the talent and resources permanently available to the industry would be

mentary legislation The President shall then transmit this report to the Congress, together with his recommendations No license for manufacture, production, export or use shall be issued by the Commission under this section until after (1) a report with respect to such manufacture, production, export or use has been filed with the Congress, and (2) a period of ninety days in which the Congress is in session has elapsed after the report has been so filed"

Although the Congress acted very wisely in anticipating that new and spectacular developments would result from atomic research, and that new problems would probably arise requiring an entirely new legislative approach, we can see, in retrospect, that there was a certain naïveté behind this provision in the law It is now fairly clear, I think, although it wasn't then, that economically feasible power from the atom will not come suddenly, but rather will follow the gradual advance of technology

If we have not yet, however, arrived at the day contemplated by the Congress when we can say "Now we have real atomic power, now we must rewrite the law," and if we probably will not arrive at that day all at once, what should we be doing now to accommodate our policies to recent technological progress and to our immediate needs for further technological advancement? In other words, what should we be doing to accommodate ourselves to the existing situation? It is now too early to attempt to rewrite the entire existing law, in my opinion For one thing, we are still in the developmental phase, and we therefore have no way of knowing exactly what will ultimately be needed in the way of a new law For another, to rewrite the law now might damage our weapons program, which still should have top priority

What we need today are policies, including some modifications in the existing law, that are tailored to fit specifically the developmental stage we are now in—policies

are built This means not simply the fuel for the first loading, but also the fuel needed for continued operation of the plant, at least for the period over which the plant is to be amortized This, too, means a modification of the Atomic Energy Act, which today gives the government the exclusive right to own fissionable materials

3 Industry must also have some assurance that there will be a relaxation of the present Commission regulations relating to secrecy, so that it can gain access to the information it needs to design, build, and operate reactors If we are to be really successful in the search for economically feasible power, our whole concept of secrecy in the reactor field will have to be radically revised, either through extensive declassification of information on power reactors, or by the establishment of a new category of secret information which can be widely disseminated to American industry but not publicly disclosed When one remembers that the Russians already have reactors producing plutonium for bombs, and considers the many administrative difficulties of establishing an "industrial secret" category of information, one is almost forced to conclude that there should be a broad declassification of reactor information in the interest of speedy progress toward the goal of economically feasible power

4 When we pass through the developmental period, in which we will be engaged for the next few years, and into the period when industry is actually building reactors with its own capital, Commission policy, and possibly the law, will have to be revised to give private investors the right to own patents

Meanwhile, to help create the technological climate needed for further rapid progress, it is quite evident to me that the government, through the Atomic Energy Commission, must continue to play a significant and leading role in reactor development, not only for military pur-

controlled by the federal government, and that the insatiable demands of the military for atomic fuel might very likely receive more consideration than they frequently deserve

By saying these things I do not mean to enter into the public-versus-private power controversy that continually rages All I mean to say is that a single federal agency should not remain in a position to own and control exclusively the entire atomic power industry that will inevitably develop in this country I would dislike seeing a municipally owned utility excluded from owning and operating a reactor as much as I would dislike seeing a privately owned utility excluded The rules should be the same for everyone, and they should be rules that are designed to accommodate anyone who has a desire to enter the field coupled with a real contribution to make

If the rules are to be the same for private industry as for the government, however, and if a climate is to be created that will attract private industry into the atomic power field on a risk basis, certain things must be done now In my opinion, they are these

1 Today there is little point for industrial concerns to spend substantial sums of money in reactor research and design when no way can be seen whereby they can construct, own, and operate reactors Industry must therefore have certain assurances that will encourage it to go much further than the study-group phase in the expenditure of funds Primarily, it must have assurance that the government means to permit private capital to build reactors and sell the power they produce This means revising the Atomic Energy Act to relax the provisions which now give the government the exclusive right to own all reactors other than low-power, research devices

2 Industry must have assurance that it can purchase and own fuel with which to charge its reactors when they

a statement of policy in the atomic power field with which I wholeheartedly agree In essence, it stated that

1 The attainment of economically competitive nuclear power is a goal of national importance Reactor technology has progressed to the point where realization of this goal seems achievable in the foreseeable future if the nation continues to support a strong development effort It would be a major setback to the position of this country in the world to allow its present leadership in nuclear power development to pass out of its hands

2 It should be the responsibility of the Commission to continue research and development in this field and to promote the construction of experimental reactors which appear to contribute substantially to the power reactor art and constitute useful contributions to the design of economic units

3 Progress toward economic nuclear power can be further advanced through participation in the development program by qualified and interested groups outside the Commission

4 There is a need for reasonable incentives to encourage wider participation in power reactor development These incentives would include

A Interim legislation to permit ownership and operation of nuclear power facilities by groups other than the Commission

B Interim legislation to permit lease or sale of fissionable material under safeguards adequate to assure national security

C Interim legislation which would permit owners of reactors to use and transfer fissionable and by-product materials not purchased by the Commission, subject to regulation by the Commission in the interest of security and public safety

poses but for general power purposes as well Although the Commission should never be in the atomic power business in the sense of building and operating large power reactors for the sale of electricity to consumers, it does, however, have the responsibility of stimulating within its own laboratories, and in industry, an intensive search for ways and means of extracting usable power from the atom We must remember that it is the Commission that owns the multimillion dollar laboratories in which most of the research work of the past has been done, and in which a large share of the research of the future will have to be performed It would be utterly unreasonable to close the door of these facilities to industry, or to expect industry to duplicate them before it could get started in the reactor-construction business

To carry out its responsibility to foster and encourage advancement of reactor technology, the Commission may well have to construct some pilot plants of varying designs and run them under conditions simulating large power reactor operations Few, if any, private concerns are in a position to place risk capital into large reactors costing $60,000,000 to $120,000,000 or more without pilot-plant experience behind them, and few, if any, would be prepared today to put risk money even into pilot plants costing on the order of $10,000,000 In close association with industrial groups, whether public or private, the Commission must, therefore, design and build and operate the forerunners of the large reactors which will someday feed appreciable quantities of electricity into the utility networks of the country If these pilot plants can also be made to do a useful job for the government while they are producing information on full-scale power plants, so much the better

In an effort to bring about this ideal of government-industry co-operation during the current development stage, the Commission, in the spring of this year, adopted

a new source of electricity that probably will take only a few pennies a month, if that, off their monthly light bill

This is, however, the case, and here is why To produce electricity an atomic power plant needs all of the electrical generating and distribution equipment that a coal-burning plant needs The only difference is that in the atomic plant the coal hopper and steam boiler would be replaced by a nuclear reactor and a different kind of steam boiler There is no chance, therefore, of reducing the cost of the plant by going to the atom for fuel As a matter of fact, it seems quite possible that atomic power plants will always cost more to build than coal plants—they certainly do now—because a nuclear reactor is, by its very nature, vastly more expensive than a coal furnace

The place, then, where you can save money by going over to atomic power is in the cost of the fuel And here you do save money, because the atom packs so much energy into such a small space This means that your fuel, per unit of heat, not only comes more cheaply in the first place, it also means that you save money all along the line on transportation, handling, and storage charges So great is this saving that some economists, when calculating the cost of atomic power, put the cost of the nuclear fuel down as virtually zero But it is important to remember that, even if coal were mined and distributed free to electric generating plants today, the reduction in your monthly electricity bill would amount to but twenty per cent, so great is the cost of the plant itself and the distribution system

To express it in the simplest terms You can save a lot of money on fuel if you have an atomic power plant, but it will cost a great deal more to build than a coal-burning plant Since atomic fuel is so cheap, you can, of course, afford to pay more for your atomic plant, but somewhere there is a ceiling below which you must stay Dr W H

D The performance of such research and development work in Commission laboratories, relevant to specific power projects, as the Commission deems warranted in the national interest

E More liberal patent rights than are presently granted to outside groups as may seem appropriate to the Commission and consistent with existing law

F Consideration of a progressively adjusted code for safety and exclusion area requirements as may appear reasonable in the light of operational experience with reactors Competent state authorities will be encouraged to assume increasing responsibility for safety aspects of reactor operation Financial responsibility associated with reactor operation will be assigned to the owners, in keeping with normal industrial practice

G Giving full recognition to the importance of reactor technology to our national security, a progressively liberalized information policy in the power reactor field as increasing activity justifies

5 It is the objective of this policy to further the development of nuclear plants which are economically independent of government commitments to purchase weapons-grade plutonium

6 The next few years will be a period of development looking toward the realization of practical nuclear power, rather than a period in which one may invest in economical (i e, large) power reactors

Among all the questions hanging over the future of atomic power, perhaps the most fundamental is this "Is it all really worth the effort?" I have heard many people express shock and surprise when they learned that about all they can expect from atomic power, at least at first, is

presently consuming energy at a rate of 20 Q per century, and that, if present trends continue, this rate will have climbed to 100 Q per century by the year 2000 This calculation includes energy consumption in all forms for propelling ships, automobiles, trains, and aircraft, for heating homes, offices, and factories, for supplying heat for industrial processes, and for producing electric power

It is sobering to match these figures against the best estimates of the world's reserves of coal, oil, and gas For economically recoverable coal, the reserve estimate is about 70 Q, and for oil and gas together it is about 8 Q If these estimates are correct, and they are probably not too far wrong, the world's fuel reserves would last for about 400 years at the present rate of consumption, and for less than 80 years at the rate of consumption that will very likely be reached by the year 2000 Whatever the margin of error here, it is plain, I think, that we cannot continue to rely forever upon our traditional sources of energy

Under these circumstances, it is encouraging to note that if all the economically recoverable uranium and thorium in the world could be converted into energy, it would provide a new source of energy amounting to about 1,700 Q, or enough for seventeen centuries even at the rate of consumption that we may expect to reach by the year 2000 When contrasted with the 70 Q in the world's coal reserves, this is an impressive figure

These facts alone are sufficient justification for trying very hard to slip a harness on the atom Moreover, I think it would be foodhardy to wait until every other kind of fuel runs out before we try to harness the atom, for there will always be special purposes for which coal, oil, and gas will be useful even in an atomic age The sooner we can take even part of the total power burden off these conventional fuels, the longer they will last to serve the purposes for which they are uniquely suited An electric power industry based on atomic energy would be a tremendous

Zinn of the Commission's Argonne Laboratory, one of the country's leading reactor scientists, has figured that one may spend no more than $60,000,000 for an atomic power plant designed to produce as much electricity (200,000 kilowatts) as a coal-burning plant costing $40,000,000 This is, of course, a permissible fifty-per-cent increase in cost over conventional facilities, and it is, essentially, the cost figure that the scientists and technicians must shoot at to make economically feasible atomic power

But even if the ultimate cost of atomic power comes out at about the same or slightly less than the cost of power from conventional sources today, it is still well worth the effort to achieve it I say this for several reasons

First, the energy the world uses today comes from coal, oil, gas, wood, or falling water Of these, all but wood and falling water, which together can supply only a fraction of the world's energy needs, are exhaustible They are being used up and they cannot be replaced Ultimately, therefore, we are going to run out of coal, oil, and gas, and meanwhile, as we work through the more accessible deposits, the cost of these fuels will steadily rise The world, therefore, is in need of a new source of energy This source is more badly needed in some countries, such as Great Britain, France, Belgium, Italy, and Sweden, where coal and oil reserves are short or nonexistent, than it is in the United States, where coal and oil are still relatively plentiful and cheap But the world as a whole, including the United States, needs a new source of energy, and it will need it increasingly as each year passes

In this situation, it is interesting to consider some facts turned up by Palmer C Putnam, a consulting engineer who recently conducted a survey on world energy sources for the Atomic Energy Commission Mr Putnam, for purposes of simplicity, uses an energy unit known as a "Q," which is equal to a billion billion British Thermal Units of heat Using this unit, it can be shown that the world is

ample, that by burning up our 100 gallons of gasoline we could change 90 gallons of water into new gasoline, and that thereafter we could, by burning gasoline in the presence of water, always make new gasoline equivalent to 90 per cent of that which we burned By such a process we could quite obviously greatly stretch out our supply of gasoline, but we could hardly expect to stretch it out indefinitely for we would always be making a little less gasoline than we consumed Ultimately we would run out of gasoline before we ran out of water, and all the rest of the water in the world would be useless to us so far as gasoline production was concerned

"But to pursue our oversimplified analogy still further, let us assume that we succeeded in developing a way by which we could produce 100 or more gallons of new gasoline from water for every 100 gallons we burned Suddenly we would have made it possible for ourselves to change gradually all of the water in the world into gasoline Our gasoline shortage would have vanished

"Scientists have known for a long time that something roughly analogous to this is theoretically possible in the field of atomic energy In atomic energy, there is only one fissionable fuel that occurs in nature It is called uranium-235, and it unfortunately constitutes less than one per cent of normal, natural uranium The supply of it that can be obtained from economically minable deposits is limited But the scientists have also known for a long time how to change another, much more prevalent, kind of uranium into fuel by burning uranium-235 in its presence They have also known that they could change thorium, another relatively plentiful element, into atomic fuel by the same process But they have never been quite sure that this fuel production process could be managed in such a way that as much or more new fuel would be created as there was old fuel consumed They thought it could be done, and they even had a name for it They called it "breed-

boon in itself, for, just in this one place, about twenty per cent of our annual consumption of coal, gas, and oil could be made available for other purposes or saved for future specialized use Another place where the atom would be of immediate benefit would be in the propulsion of ships If our entire Navy and merchant marine were converted to atomic energy, a substantial percentage of our oil reserves could be immediately conserved for later use for such purposes as automobile propulsion—a function to which a nuclear reactor, with all its bulky shielding, may never be suited

In all of these energy calculations there has until recently been one highly important "if" Thus, we could expect to find these great quantities of energy in the atom only *if* we could convert all of the economically minable uranium in the world into fissionable material And we could stretch these even further only *if* we could also convert all of the economically minable thorium in the world into fissionable material In this connection, I had the great pleasure of making the following announcement shortly before I completed my term as Chairman of the Atomic Energy Commission

"We have now reached still another milestone in the history of atomic energy development in this country It is a development which holds out the promise of making a civilian atomic power industry even more feasible and attractive in the long range than it has hitherto appeared to be

"To explain to you the impact of reaching this new milestone, I would like to use an analogy, albeit a greatly oversimplified one I would like to ask you to imagine a world in which only one hundred gallons of gasoline existed When that gasoline was used up, gasoline would forever be gone from the earth But let us imagine that we could make gasoline out of water by burning the gasoline we had in the presence of water Let us say, for ex-

from it. Breeding is a slow process, and a reactor may have to operate for five years or longer before it succeeds in yielding as much new fuel as was initially invested in it. Our great current demand for uranium-235 and plutonium for weapons, and our equally great need for raw uranium ore to meet this demand, will not be lessened one iota.

"The real significance of breeding is that it is now possible for mankind ultimately to utilize all of the uranium that can be extracted from the earth's surface for atomic fuel, whether it is fissionable or not in its natural state. This proof of success in breeding at the Idaho station suggests, in addition, that the other potential atomic fuel, thorium, may also ultimately be utilized. Thorium, however, was not used in this particular experiment, and I do not wish to imply that its susceptibility to breeding has been proved.

"In summary, I should like to emphasize that the achievement of breeding with uranium is an important event, but it is not one that is likely to cause any immediate, or even imminent, revolutionary change in the economics of atomic power production. What it constitutes, mainly, is another encouraging and important factor which can be introduced into the many calculations being made to determine the best technical and economic approach to real, competitive atomic power."

The atom, then, is a promising new and relatively plentiful source of energy for replenishing the world's dwindling supplies of energy. But this is only one reason why it is worth developing. Consider, too, the unique characteristic of the atom as a fuel: its virtual weightlessness. This means that it can be taken anywhere in the world cheaply—to the Arctic, to the desert, to an island—whereever it is difficult, costly, or impossible to take coal and oil today. To me, this has enormous implications. Visualize, for example, a desert region that could be irrigated

ing," and it was in an effort to find out for certain whether this breeding process was possible in a particular type of reactor that the Argonne National Laboratory designed and built the Experimental Breeder Reactor in Idaho

"This, you will recall, is the same reactor that first produced atomic power in 1951 I now have word that Dr Walter Zinn, Director of the Laboratory, Dr Harold Lichtenberger, in charge of the breeder project, and their Argonne colleagues have used the reactor to demonstrate successfully the principle of breeding The reactor is operating in such a way that it is burning up uranium 235 and, in the process, it is changing non-fissionable uranium into fissionable plutonium at a rate that is at least equal to the rate at which the uranium-235 is being consumed Breeding has been achieved, and Dr Zinn and his colleagues are to be congratulated for bringing us to another important milestone in the development of atomic energy

I think, however, that we must take care to see that this encouraging development is kept in its proper perspective This news does not mean that economic power from atomic fuels is here It does not mean that overnight we have suddenly obtained all the fissionable material we want or need It does not mean that uranium can now be regarded as a virtually costless fuel It is quite possible that the breeding principle will not even be incorporated in the first atomic power plants It may be that some other types will be more feasible from the economic point of view, at least at first and possibly for some time A large-scale breeder reactor can be a costly proposition It requires a very large initial investment of scarce fissionable fuel In addition, before the newly created fuel can be extracted and put to use, it must go through a chemical separation process which is currently one of the most expensive aspects of the atomic energy business

"The achievement of breeding also does not mean that we are suddenly independent of raw uranium ore Far

tion of electric energy and the production of heat to propel various means of transportation What is beyond these no one today knows At the time when Morse sent his famous "What hath God wrought? message over the first wireless, how many people could visualize the progress in the field of electronics that has led to radar and television? Even if we had no other reason to apply ourselves diligently in the field of atomic power, our current ignorance of the art and the obscure but tantalizingly promising future should be enough in itself to beckon us on

if there were only enough cheap power to pump in a supply of fresh water Visualize also a barren coastal region that could support a civilized community if only there were enough cheap power available to distill sea water into fresh water And visualize a world economy released from the heavy expense of transporting bulky fuels Because of the great cost of shipping coal and oil, industry today tends to locate near its sources of power, and this is not always where its raw materials are found This means that the raw materials must be shipped in, frequently an expensive operation in itself With atomic power, however, the fuel can be taken cheaply to the raw materials Thus many parts of the world, rich in certain resources but poor in power, will find it possible to process their raw materials cheaply at home and ship out the much lighter and less bulky final product This will not only reduce the cost of the final product to the consumer, it bids fair to change the industrial and economic geography of the world

The extreme compactness and virtual weightlessness of the atom as a fuel also has significant implications in the field of transportation Although the shielding is bulky and perhaps always will present a problem where small vehicles, such as automobiles, are concerned, the saving in fuel weight and storage can make up for this in the case of commercial ships, as it may ultimately in the case of commercial aircraft and trains One field, now inactive, which conceivably could be revived by atomic power is that of lighter-than-air craft, where the atom's non-inflammability (in a chemical sense) and extreme compactness could easily prove to be an important boon

Perhaps the most challenging and provocative aspect of atomic power lies, however, in areas not yet thought of The potential applications I have discussed are those that we can visualize and work toward today, even at this early stage of development They include mainly the genera-

the constituent parts of an atom During the prolonged discussion many of the more erudite members of the press asked questions which were answered in considerable detail

Finally the questioning stopped, and the scientists who had undertaken to cover this particular subject prepared to move on to another But before doing so they invited a last question or two from anyone wishing to clear up a point that might not yet be fully understood In response, the man who had asked the original question raised his hand, very thoughtfully leaned forward, and said "There is one small point I am not yet completely clear on What exactly," he inquired, 'is an isotope?'

It is this inability of most people to understand what an isotope is that has, in my view, prevented isotopes from receiving the credit they deserve for the contribution to human betterment they have already made in this very early stage of atomic energy development Actually isotopes constitute perhaps the happiest chapter in the story of the atom They are used to treat the sick, to learn more about disease, to improve manufacturing processes, to increase the productivity of crops and livestock, and to help man to understand the basic processes of his body, the living things around him, and the physical world in which he exists Here, in the field of isotopes, there are no difficult questions of policy to thrash out, and very few questions of law or economics to decide And there is no question of waiting for benefits to materialize in the future They are here now—at least some of them—and they are already beginning to change and improve our lives in many more ways than most people realize

But just what is an isotope? I am not sure I can succeed in making this clear where others have failed Perhaps the best definition I have ever heard is this "An isotope is something that is exactly like something else only it is

CHAPTER *x*

Radioisotopes: Servants of Man

I REMEMBER a press conference which took place at Atomic Energy Commission headquarters in Washington shortly after I became a Commissioner The purpose of the conference was to familiarize the members of the press with the many beneficial things that were being accomplished throughout the world by the use of those valuable by-products of the atomic energy program called "radioisotopes" As a Commissioner, I was expected to be on hand for the conference, but as a new Commissioner I was not expected to say much Present to answer the technical questions of the press were several scientists from the Commission's staff This was an excellent arrangement from my point of view, for I was not yet very familiar with the isotope part of the atomic energy program, and I welcomed the opportunity to listen and learn

I well remember the first question from the floor "Just what,' asked one gentleman of the press, 'is an isotope?" There followed a rather lengthy discussion about atomic weights and masses, mixed in with numerous references to neutrons and protons, the composition of atomic nuclei, and the periodic table of the elements A blackboard was brought out and several diagrams were drawn upon it with a good many white and black circles representing

ferences even among the atoms which go to make up single elements Thus, all hydrogen is not exactly like all other hydrogen, and all gold, silver, oxygen, and uranium is not exactly like all other gold, silver, oxygen, and uranium Mainly these differences have to do with weight (some types of one element are very slightly lighter or heavier than others), but in many other cases they also have to do with radioactivity Some types of one element send out invisible rays like X rays, while others don't Substances that emit these rays, or 'atomic sparks" as they are sometimes called, became known as "radioactive" The most widely known naturally radioactive substance is radium

Having given the name "elements" to the ninety-two basic substances of the earth, man needed a new name for the different types of substances of which each individual element is composed The name he chose was "isotopes,' which stems from the Greek words *iso*, meaning "same,' and *topos*, meaning "place" The name was first suggested in 1913 by the British scientist Frederick Soddy, who was then one of the leading research workers in the atomic field

Hence we can see that an isotope really is "something that is exactly like something else only it is different" An isotope of gold is gold, but it is not quite like all other gold An isotope of sodium is sodium, but it is not quite like all other sodium Unless the isotope is radioactive, it can be distinguished from other types of the same substance only by the most intricate laboratory equipment But if it is radioactive, it can be identified by instruments, such as the Geiger counter, which are used to detect nuclear radiations

An isotope is generally designated by a numerical figure representing the number of particles in the nucleus of one of its atoms Thus we have hydrogen-1, with one particle in its nucleus, hydrogen-2, with two, and hydrogen-3, with

different." At first glance, this does not appear to shed much light on the question of what an isotope is. But perhaps it can be made to if we look briefly at a little history.

When man began his life on earth he found things around him which he could identify. He identified the air he breathed, the water he drank, the plants and animals he ate, the wool and coal he burned, the stone and earth from which he built his shelter, and the salt with which he seasoned his food. As time passed he learned that most of these things were made up of other, more basic substances. Thus he found that water was really made up of the gases oxygen and hydrogen and that salt was made up of sodium and chlorine combined in a way that completely changed the characteristics and properties of the original substances. Ultimately he discovered that there were only ninety-two substances that occurred naturally on earth and that were not combinations of something else. They were "pure." All other things, he learned, were really combinations of two or more of these basic building blocks which, because of their elemental nature, he called "elements." Among the ninety-two basic elements he identified such very light substances as hydrogen, carbon, and oxygen, such heavier substances as silver, iron, and zinc, and such very heavy substances as gold, uranium, and lead.

For a very long time man thought that all of the material which went to make up any one of these ninety-two basic elements was exactly alike. Thus, he thought that all hydrogen was identical with all other hydrogen, and that all uranium was identical with all other uranium. There was a very good reason why he should believe this, for all hydrogen looked and acted like all other hydrogen and all uranium looked and acted like all other uranium. In fact, this appeared to be true of every one of the ninety-two basic elements he could separate and identify.

But now man realizes that in some cases there are dif-

of very much value in the tracing of biological and industrial processes because radium is not a particularly important element in these processes What was needed were some radioisotopes of such common and vital elements as sodium, phosphorus, iodine, iron, and sulfur, and these, unfortunately, do not occur in nature If man was to have them, they would have to be made artificially

The first artificial radioisotopes were made in the 1930's in such giant atom-smashing machines as cyclotrons A cyclotron is essentially a giant rifle designed to shoot minute atomic particles at the nuclei of various elements Some of these particles strike the nuclei with such force that they knock very small pieces of them out and rearrange their basic structure This changes the bombarded material into a different element It is the process called "transmutation," which was the dream of the alchemists who hoped to change base metals into gold Today we have exceeded their dreams, for we can transmute ordinary elements into substances far more valuable than gold

With the invention of the cyclotron, investigators at last had a way of producing the tools with which they could trace specific atoms through various reactions with amazing sensitivity and without disturbing life processes In addition, some radioisotopes could be used, like X rays or radium, as sources of nuclear radiation which would penetrate solid matter and destroy diseased tissues

The only trouble was that there weren't enough radioisotopes to go around Atom-smashing machines can produce radioisotopes only in the most minute quantities Nearly all of the volume of an atom is empty space, and the chances that a nuclear bullet from a cyclotron will hit a nucleus are very small Thus only a few investigators were able to obtain radioisotopes, and the number of experiments in which they could be used was limited by the available supply

This was the situation which prevailed when the United

three By the same token we have oxygen-16, 17, and 18, and uranium-233, 234, 235, and 238 Of these, uranium 235 is particularly interesting because it is the only naturally occurring substance whose atoms are constructed in such a way that they can, as we have seen in previous chapters, be made to undergo fission Uranium-233 is also fissionable, but, like plutonium, it is man-made

Isotopes which are radioactive are known as "radioisotopes" * These radioisotopes are of special interest to the research worker because they can be so easily detected by such instruments as the Geiger counter Less than a billionth of a billionth of a gram of some radioisotopes can be detected Thus, if a very small amount of a radioisotope of any given element is introduced into a large quantity of that element, the course of the element s progress through any biological or industrial process can be accurately traced This, for the first time in history, gave man the power to watch such processes while they were actually going on In the words of one leading biologist, Dr Melvin Calvin of the University of California, "It was as though the scientists had been given an eye which could look into plant cells and which could see the actual processes taking place" As an indication of the decisive way in which these radioactive materials assert their presence, 1/100,000th of a gram of carbon-14 (a radioisotope of carbon) can be accurately measured when spread through the tissue of 20,000 guinea pigs

Until 1934, virtually the only radioisotopes that were sufficiently active to be of much use were those of the element radium and its decay products As almost everyone knows, the radiations sent out by radium have been widely used in the treatment of cancer and for activating certain chemicals to illuminate watch dials But they were never

* Some radioisotopes remain radioactive longer than others Some last billions of years others only fractions of a second. The time it takes a radioisotope to lose half of its radioactivity is known as its "half life

War II as a pilot plant for plutonium production The radioisotopes are priced on the basis of actual production cost, and those used for cancer research, diagnosis, and therapy are provided at twenty per cent production cost Stable (that is, non-radioactive) isotopes also are produced at Oak Ridge with different equipment Although they are not as sensitive research tools as radioisotopes, they are useful in some investigations, particularly in research involving elements which do not have suitable radioisotopes More than 2,000 shipments of stable isotopes have been made from Oak Ridge since 1946

A reactor produces radioisotopes in three ways, all of which utilize the neutrons which circulate in great profusion throughout a nuclear reaction If the neutrons are absorbed by the nuclei of atoms of a target element placed in the reactor, heavier isotopes of the same element are produced If neutrons knock particles out of the target nuclei, isotopes of a different element result And if neutrons hit the nuclei of uranium-235 atoms, these nuclei split into two pieces, each a radioisotope of a lighter element The radioisotopes formed by this last process are called fission products

Most of the radioisotopes distributed by the Atomic Energy Commission have been used for biological and medical research and for medical diagnosis and treatment In medical research, they are used as tracer atoms to increase understanding of various body processes and organs For such research, radioisotopes frequently are incorporated into chemical compounds before being administered to a human being or laboratory animal Some of the compounds which are important in life processes can be manufactured in the laboratory, but others can be produced only by plants or animals

The most useful of these compounds have been obtained by growing a variety of food and medicinal plants in an atmosphere containing carbon dioxide into which radioac-

States succeeded in creating a self-sustaining chain reaction in uranium 235 during World War II Immediately there was opened up the *possibility of producing* quantities of radioisotopes—many thousands of times the number that could be produced previously, and at a cost many times less

The atoms of a substance placed in a nuclear reactor are exposed to a bombardment far more intense than that produced by a cyclotron As many as a million million neutrons flow through each square centimeter of a reactor each second, and this neutron flow exists in a volume occupied by many tons of uranium and graphite In a few weeks one nuclear reactor can produce at a cost of about $10,000 as much radioactive carbon as one thousand cyclotrons could produce at a cost of more than $100,000,000 During the five years from 1946 to 1951 the reactor at Oak Ridge National Laboratory produced radioisotopes with about four hundred times as much radioactivity as those produced in approximately fifty cyclotrons throughout the nation during the same period

Officials of the Manhattan Engineer District realized that radioisotopes were a valuable by-product of the development of atomic energy After the wartime secrecy restrictions on the atomic energy program were removed, the Manhattan District began a program of distributing reactor-produced radioisotopes to private institutions for research This program was taken over by the Atomic Energy Commission and has been expanded until more than a hundred different types of radioisotopes are available Since 1946 about 35,000 shipments of radioisotopes have been made to about 1,000 institutions throughout the nation In addition, nearly 2,000 shipments have been made to about 250 institutions in 31 foreign countries

Most of the radioisotopes distributed by the Commission are produced at Oak Ridge National Laboratory in an air-cooled, graphite-moderated reactor built during World

stantly are engaged in a dynamic process of breakdown and rebuilding. This process can occur with surprising speed. Salt injected into a vein, for example, will diffuse through the vein wall, go to the sweat glands, undergo conversion to sweat, and travel to the outside of the body —all in less than a minute. We have watched this process take place, tagged it and timed it.

More complete understanding of the complicated compounds involved in biochemical reactions is expected to throw new light on cancer. This is particularly true of research involving the nucleoproteins, the giant protein molecules on the border line between living and non-living matter. Cancer is essentially a cell disease, and it is possible that it occurs when the nucleoprotein material in cells, for some reason or reasons not yet understood, reproduces itself in an uncontrollable manner. Experiments involving the isotopic labeling of various components of nucleoproteins should provide a better understanding of their role in cancer. If man ever learns to control cancer, it probably will be through this slow, hard basic research into what makes living matter behave as it does and why cell growth sometimes goes wild.

In the meantime, radioisotopes have found varied uses in the diagnosis and treatment of cancer, as well as other diseases. As tracers for diagnosis, they are used in amounts that will not injure body processes. All nuclear radiations can damage cells, however, and this property is used to advantage to destroy diseased tissues. For this purpose, radioisotopes may be beamed into the body from the outside, like X rays, or they may be administered internally, either directly into the blood stream, by mouth, or by injection into a tumor or a body cavity.

The most useful radioisotopes for diagnosis are radioiodine and radiophosphorus. Radioiodine, like ordinary iodine, accumulates in the thyroid gland. A few hours after a patient drinks a solution of radioiodine in water—the so-

tive carbon has been introduced The plants incorporate the radioactive carbon into their cells, and various substances, all "labeled" by the radiations which they emit, may be extracted These substances may be fed to animals, and other compounds, still carrying the telltale radiocarbon label, may be extracted from the blood, urine, and tissues

Radioisotope-labeled compounds include sugars, organic acids, amino acids, starch, proteins, pigments, and alkaloids A number of labeled drugs have been produced in this fashion, for example, radioactive digitalis may be extracted from foxglove plants grown in an atmosphere of radioactive carbon dioxide

The value of such compounds in studying life processes is very great Various drugs can be tracked through the body and their action observed The role in body mechanisms of the large, complex molecules which make up such substances as proteins, nucleoproteins, and enzymes can be studied more accurately than ever before Cancer-producing chemicals can be traced, and differences in metabolism between cancerous and normal cells can be detected Hundreds of experiments are being carried out with radioisotopes in these fields Radiocarbon also has been used to analyze the way in which the body uses food energy to build amino acids into proteins

Other experiments with radiocarbon and radioiron have thrown light on such diseases as anemia and diabetes Research utilizing radiozinc has demonstrated that the white blood cells of leukemia sufferers are deficient in this element This may help in understanding why overproduction of white blood cells occurs in this disease

Through the use of isotope tracers, investigators have built up a picture of the living body which is quite different from the conventional idea that the body is a more or less stable, unchanging structure Instead, the various body organs—even such solid parts as the bones and teeth—con-

alleviate the painful symptoms of angina pectoris and congestive heart failure Inhibiting the activity of the thyroid slows body processes, easing the load on the diseased heart

Radiophosphorus also has been a valuable diagnostic tool in locating certain types of brain tumors during surgery These tumors absorb many times more phosphorus than normal brain tissue, and 'tagged' phosphorus injected into the veins of the patient accumulates in the tumors Since the radiations penetrate only about a quarter-inch of tissue, a special radiation detection instrument, with a needlelike probe which can be inserted into the brain, must be used in association with the radioisotope

Another promising technique for treatment of brain tumors has been developed at Brookhaven National Laboratory Patients are given injections of boron-10 and shortly afterward are exposed to neutrons from the nuclear reactor at the laboratory The boron accumulates in the tumorous tissue, and the neutrons split the boron atoms into two fragments, each of which acts as a source of very intense but short-ranged radiation The range of the radiation is less than a millimeter, so the treatment can be extremely selective Eight out of ten patients given this treatment have showed improvement

Radiophosphorus has been used in the treatment of cancer of the lymph system and for treatment of leukemia, a cancerlike disease in which white blood cells are produced at an abnormally high rate It has not accomplished cures, but it is believed to have prolonged the lives of some patients It has been much more successful, and, in fact, is the preferred treatment in cases of polycythemia vera, a disease characterized by overproduction of red blood cells

If radioisotopes can be guided to other cancerous organs by the body itself, as radioiodine is guided to the thyroid gland, new techniques of treating inoperable cancers may

called "atomic cocktail"—more than half of the radioisotope will be concentrated in the few ounces of tissue making up the gland A cancerous thyroid doesn't take up as much iodine as a normal gland, an overactive thyroid will accumulate more than normal A tracer dose of radioiodine will indicate the gland's health and activity A larger dose may be used to inhibit growth of the cancerous cells

Since cancerous thyroid cells take up less radioiodine than normal cells, the isotope has not proved to be as helpful in the treatment of thyroid cancer as was at first hoped However, it has proved to be valuable in tracking down and inhibiting the growth of any fragments of cancerous tissue which may have spread from the thyroid to other parts of the body When the gland itself is removed by surgery, these fragments increase their iodine-accumulating activity and become more vulnerable to radioiodine treatment Cancer nodules in the jaw and lungs have been treated in this manner

A few months ago investigators at the University of California in Berkeley developed a device called a "gamma ray scanner" which may be used in association with radioiodine to detect thyroid cancerous growths in various parts of the body A movable portion of this apparatus, bearing a series of small radiation detectors which record as dots on a photographic film, is passed over the reclining patient By this scanning procedure, an image of the patient is formed as a pattern of dots, each one of which represents a given degree of radioactivity

Probably the most successful therapeutic use of radioiodine has been in the treatment of hyperthyroidism, or overactivtiy of the thyroid The radioisotope bombards the gland with short-range radiation called "beta rays, damaging sufficient cells to slow down the abnormal activity Since the beta rays travel only about one eighth of an inch in tissue, their damaging effect is confined virtually to the gland itself The same treatment has been used to

cerous site deep within the body When this is done, the cancer cells receive a damaging amount of radiation, the intervening tissue does not The Canadian reactor at Chalk River, Ontario, has been particularly useful in producing high-intensity radiocobalt sources because of the radiation level at which it operates Radioactive cesium, one of the fission products produced by a reactor, may ultimately turn out to be a better radiation source than radiocobalt because of its longer half-life Facilities for separating it in quantity from the other fission products resulting from reactor operation do not exist as yet, however

Another useful radioisotope in the treatment of disease is radiogold, which, incidentally, is one of the least expensive of radioisotopes Cancer tissues in a body cavity frequently lead to the formation of excess fluids Radiogold injected into the cavity inhibits the cancer cells and also slows down the secretory activity of the normal cells lining the cavity Radiogold also may be injected directly into tumorous tissue

The value of radioisotopes in the treatment of cancer should not be exaggerated, however This was brought home to the individuals connected with the atomic energy program last year, when Senator Brien McMahon, author of the Atomic Energy Act and Chairman of the Joint Congressional Committee on Atomic Energy, died of cancer No one had been more active in furthering the peacetime applications of atomic energy Yet no radioisotope—no technique developed in the fight against cancer—could save his life

One of the most valuable uses of radioisotopes is to gain understanding of the life processes of plants as well as of animals and human beings Probably the most fundamental of these processes is photosynthesis, the process which enables plants to utilize water, carbon dioxide, and the sun's energy to build up carbohydrates, proteins, and fats and give off oxygen Photosynthesis is the source of

well result Investigators are consequently attempting to develop radioactive "guided missiles" for this purpose These missiles are called "antibodies"—substances built up by the body to resist alien material The technique works in this way If kidney tissue from a mouse is injected into a rat, the rat will build up an antibody to fight the intruding substance This antibody may then be extracted from the rat and placed in a solution of radioactive material, some of which it will absorb If the antibody is then injected into a mouse, it will travel directly to the mouse's kidney, carrying the radioactivity along with it

In April 1953 scientists at Sloan-Kettering Institute announced what appears to be an important advance in this technique They reported the development of cancer-cell antibodies which travel through the body directly to cancerous tissue These antibodies can be made radioactive If they may be used safely in the human body, it is hoped that they may be used to carry radioisotopes to a number of different types of cancerous tissue which cannot be treated in any other way

Radiocobalt has proved to be the most valuable radioisotope of all for use, like an X-ray machine or radium, as an external radiation source It can be produced readily in a reactor It is far cheaper than radium and is easier to use than X rays It may be machined into various shapes to fit different parts of the body, or it may be made in the form of needles or beads to be placed directly in diseased tissue Even radiocobalt-nylon thread has been used to place radioactivity in a cancerous tissue Radiocobalt is also easier to handle, because it is so malleable, and requires less shielding than radium

Several high-intensity radiocobalt sources of radiation are in use within the United States for medical purposes One of these may give off as much radiation as more than two pounds of radium Interestingly, wafers of radiocobalt can be arranged so that their radiations converge at a can-

fectively, what fertilizers are best for various types of soils, and how the fertilizer is taken from the soil and used by the plant

A single research project, conducted at North Carolina State College, saved North Carolina farmers an estimated 4,300 tons of superphosphate a year by demonstrating that tobacco plants cannot utilize phosphate fertilizers put on the surface of the soil during the growing season Studies of phosphorus uptake in truck crops in New England showed that farmers apply considerably more phosphorus than these crops take out of the soil Other experimentation has indicated that winter killing of alfalfa and some other plants may be reduced by applying phosphates during the winter season

Some plant diseases apparently occur when mineral nutrients from the soil become bound up in insoluble compounds in the plant tissue Radioisotopes are being used to determine how and why this process occurs Tracer studies indicate that chlorosis, a widespread disease of fruit trees, may be caused by alkaline soils which interfere with the utilization of iron, zinc, copper, and manganese by the trees

Radioiodine has been used to trace the intricate, intermingled root systems of stands of oak trees The course of the radioisotope through the roots indicates that the disease may be spread from one tree to another by root grafts Pole blight in pine also is being studied through the application of tracer radioisotopes to the roots

Radioisotopes are also used in various ways to combat crop pests Flies and other insects can be tagged with radioisotopes and their migrations studied Dispersal of air-borne fungi can be traced in the same way Tracers also are being used to gain information on the action of insecticides and weed-killers Tracer research with DDT has indicated recently that DDT-resistant flies are able to

all our food, as well as of all our coal and oil In addition, it constantly replenishes the oxygen in the atmosphere that is used up by animal life and by the burning of fuel

The end products of photosynthesis have been known for some time, but just how the complicated carbohydrate, protein, and fat molecules are built up from simple elements has been one of the most mysterious processes in nature Now, by growing plants in an atmosphere containing carbon dioxide labeled with radiocarbon, investigators have been able to follow some of the steps in this process

Like the reactions in animal metabolism, the steps in photosynthesis occur with surprising rapidity Tracer experiments show that radiocarbon is incorporated into two or three compounds in the first two seconds after it is taken in by a plant In one minute at least fifty compounds will be formed, and in two minutes the radiocarbon is incorporated into the complicated amino-acid compounds which go into the building of proteins If investigators succeed in identifying and synthesizing all of these compounds, it may be possible to synthesize food and fuels from elements and energy This single accomplishment might well change the conditions of human existence more drastically than all of the work in the field of nuclear-powered ships, airplanes, and electric generators

Other uses of radioisotopes are bringing more immediate benefits in plant science These include studies of the way plants utilize fertilizers and various materials from the soil, as well as methods of controlling insect pests and weeds

Isotope research has shown farmers how to utilize fertilizers more efficiently Through the use of radioisotopes *in plant food, investigators have been able to determine* where and how fertilizer should be placed for maximum uptake by various plants, when the plant uses it most ef-

fectively, what fertilizers are best for various types of soils, and how the fertilizer is taken from the soil and used by the plant

A single research project, conducted at North Carolina State College, saved North Carolina farmers an estimated 4,300 tons of superphosphate a year by demonstrating that tobacco plants cannot utilize phosphate fertilizers put on the surface of the soil during the growing season Studies of phosphorus uptake in truck crops in New England showed that farmers apply considerably more phosphorus than these crops take out of the soil Other experimentation has indicated that winter killing of alfalfa and some other plants may be reduced by applying phosphates during the winter season

Some plant diseases apparently occur when mineral nutrients from the soil become bound up in insoluble compounds in the plant tissue Radioisotopes are being used to determine how and why this process occurs Tracer studies indicate that chlorosis, a widespread disease of fruit trees, may be caused by alkaline soils which interfere with the utilization of iron, zinc, copper, and manganese by the trees

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break the insecticide down into non-toxic products, but that various chemicals may be added to make DDT effective against these resistant insects

One of the important characteristics of nuclear radiations is that they can cause sterility in animals and plants This fact is the basis for a novel use of radioisotopes to control an insect pest which causes many millions of dollars worth of damage to livestock annually Large numbers of laboratory-raised male screwworm flies are sterilized by gamma rays from radiocobalt Female screwworm flies mate only a single time, so if many sterile male flies are turned loose in an infested area, a number of the females will mate with sterile males and produce infertile eggs This ingenious pest-control experiment is being tried for the first time this year by Raymond C Bushland an entomologist for the Department of Agriculture If it is effective, the same principle could be applied to decrease the numbers of other insect pests

Radioisotopes are being applied in industry as well as in biology, medicine, and agriculture Utilization of radioisotopes in industrial research ranges from basic studies in organic and physical chemistry to studies of the efficiency of kitchen food-mixers or the distribution of water in precooked rice Radioisotopes also are being used in various industrial processes, to control machinery and to detect the presence of various materials Some specific applications are as follows

Thickness gauges

A radioisotope is placed on one side of a moving sheet of material, such as paper, rubber, plastic, or thin metal, and a detection instrument is placed on the other side The amount of radioactivity measured by the instrument indicates the thickness of the sheet, and variations can be corrected automatically

Radiography

Radioisotopes can be used like X rays to detect invisible

flaws in castings, welds, and forgings They are less expensive and easier to handle than X rays

Leak location

Minute leaks in complicated systems of pipes can be detected by radioactive tracers, even when the pipes are behind walls

Tracing the flow of liquids through pipelines

Some industrial pipelines are hundreds of miles long, and various liquids may flow through them in succession To prevent these from being mixed when they are drawn off, it is necessary to know exactly where one liquid ends and the next begins as they travel through the pipe This dividing line can be located easily by placing a small quantity of a radioisotope at the junction between the two liquids When the radioactive material reaches a take-off point, the radioactivity registers on a detection instrument

Safety devices

A safety unit has been developed which consists of a radioactive wrist band worn by a machine operator, and a detection instrument on the machine If the operator's hand enters a dangerous area, the increase in radioactivity from the wrist band operates a control which stops the machine

These are just a few of the many examples of the uses of radioisotopes in industrial processes They have had even wider application in industrial research Perhaps the simplest such application is the use of radioisotopes to measure the transfer from one surface to another of minute amounts of materials, such as the metal worn from a moving part of a machine by friction Wear of piston rings or gears may be measured by making them radioactive and then measuring the amount of radioactivity found in the lubricant after use The California Research Corporation has stated that by this technique it is accomplishing in four years and with an investment of $35,000 what

would have required sixty years and an investment of \$1,000,000 without radioisotopes Wear of automobile tires can also be measured in the same way by incorporating a radioisotope into the tread, and this is being done by a number of leading rubber companies

One of the newest applications of the tracer technique to the measurement of wear provides a good illustration of its advantages Before isotopes, studies of wear of the cutting edges of machine tools took almost the entire life of the tool Now the amount of wear of a tough edged cutting tool can be measured accurately after only six to thirty seconds of use

Other industrial research involving tracer radioisotopes includes studies of the efficiency with which various detergents remove dirt from the family wash, the processes involved in the flotation of mineral ores, the effectiveness of the preservatives used on telephone poles, and the reactions involved in the production of synthetic gasoline from coal and natural gas

In addition to these uses, the nuclear reactor provides a new analytical technique for industry When a substance is placed in a reactor, tiny amounts of impurities may be made radioactive Impurities in foods, drugs, metals, and other materials which cannot be detected by other methods can be measured accurately by this technique

Earlier in this chapter it was noted that one of the three sources of reactor-produced radioisotopes is the fission of uranium atoms into smaller, radioactive parts These parts, or fission products, are a by-product of reactor operation So far, they have been considerably more of a nuisance than a benefit Like ashes in a furnace, they accumulate to a point where they interfere with the operation of the reactor, and they must be separated from reactor-produced plutonium before it is usable Most fission products are not used today, but are stored in huge underground tanks However, these waste products con-

tain tremendous amounts of radioactivity, which might be used by industry in various ways

Possible uses of fission products have been studied by the Stanford Research Institute under contract with the Atomic Energy Commission A report issued by this organization in 1951 indicated that a potential large-scale industrial demand exists for fission products, but that the magnitude of the demand will depend greatly upon price If fission products can be sold very cheaply, large quantities might be used by industry

Before fission products can be made available to industry on a large scale, however, both technical problems (such as the design of separation plants) and marketing problems (such as pricing, patent, and safety policies) will have to be solved Separation processes are particularly costly today, and a good deal of research may have to be done before fission products become an economically feasible proposition In addition, industry will have to know considerably more about their utilization than is known today Several fission-product sources of high-intensity radiation are being used in research in this field

If fission products can be made available to industry at $100 per curie (a 'curie" is equivalent to $20,000 worth of radium) or less, the Stanford Research Institute has reported they could be used for static eliminators, for making permanently fluorescent light tubes, and for manufacturing new types of chemicals If the price were brought down to $5 per curie, their use in industrial radiography would be practical At $2 per curie they could be used for sterilizing various drugs, such as penicillin, without the use of heat Below $1 per curie, the Institute has concluded, they might be used for the sterilization of various foods

This last use is problematical at our present stage of knowledge Destruction of all micro-organisms in food requires a very high dose of radiation, and the amount

necessary may affect the taste or even produce toxic substances Sterilization of drugs is a more promising possibility, at least in the immediate future

In this chapter I have tried to review some of the ways in which radioisotopes now are being used in biology, medicine, agriculture, chemistry, and in various industries No one can predict today all the other uses which may be developed Future applications of radioisotopes, particularly in research, are limited only by the ingenuity of the men who use them But it is safe to say that they will continue to be powerful and versatile research tools as long as man seeks to increase his understanding of the processes of life and the nature of the world around him

CHAPTER *xi*

The Quest for Knowledge

IF you have ever looked through a powerful telescope at the night sky, or visited a planetarium, you probably have at least a faint idea of the kinds of worlds that exist beyond the range of human experience and understanding

One such world is the world of the atom Unlike the Milky Way or the Spiral Nebula, however, no one has ever seen an atom, even in broad outline Atoms are far too tiny They are as infinitely small as the universe is infinitely large Even the most powerful microscope fails by many thousands of times to bring the bulkiest atoms into view And yet, by developing many theories, by testing them over many years of painstaking experimentation, and then by revising and adjusting them until they explain at least in part the things that happen in the world that man understands and knows, man has succeeded in learning a good deal about atoms and what they can be made to do

Surprisingly enough—or perhaps unsurprisingly—the world of the atom, as currently visualized by man, is not too different from that of the stars If you could reduce yourself in size until you were even smaller in relation to an atom than you now are in relation to the earth, you could enter this world What you would find there no one

really knows, but you would probably find something that was not vastly different from what you might encounter if you were traveling in a space ship deep in the Milky Way Most of the space around you would be completely empty, and yet, at intervals, for as far as your eyes could see, there would be "suns" and "stars" and "planets" There would even be "comets" and "meteors" and, here and there, an exploding star or one that was, by violent eruption, disgorging fragments of itself out into atomic space

Such, according to what we know today, is the world of the atom It is an orderly world, and yet, so far as man is concerned, it is a complicated and still largely mysterious one Man has learned a lot about this world, but, as with the universe itself, the more he learns the more there seems to be to learn The really fundamental truths always seem to lie just beyond the reach of the most brilliant human minds and the most intricate man-made equipment But in spite of these many drawbacks, man today knows, or thinks he knows, enough about atoms to be able to construct, in general terms, a fairly clear if symbolic picture of one

According to current theory, an individual atom is similar, roughly, to the solar system of which our earth is a part It has a dense, inner core, called a "nucleus," corresponding to the sun, and one or more incredibly small surrounding particles called "electrons," corresponding to the planets If you could enlarge an average-sized atom until its nucleus was as big as a basketball, its electron planets would be about a mile away So small is the nucleus, however, that if you took a bowl of water and increased it in size until it was as big as the earth, you would still need a microscope to distinguish the individual nuclei and electrons within it

Man has known for a long time that the nucleus of an

atom and the electrons which surround it are both electrically charged, with the nucleus bearing a positive charge and the electrons a negative one He has also known for many years that the electrons in an atom are but loosely bound to their nuclear "sun" by this electric attraction, and that it is interactions between the electrons of different atoms that build the molecules of the substances which make up the world as you and I know it These electronic interactions, for example, account for the way in which atoms of oxygen and hydrogen can be bound together to form water They also account for such ordinary chemical reactions as the burning of coal, the manufacture of drugs and chemicals, and the explosion of dynamite But the hearts of atoms—their nuclei—are undisturbed by these sometimes violent goings-on along the outer edges of their atomic domains They can even preserve their nuclear equanimity through the explosion of a TNT blockbuster bomb

It is with these atomic nuclei that the science of atomic energy deals The purpose of the atomic energy program is to learn as much about these hearts of atoms as possible, and then to put that knowledge to work As yet, scientists do not know very much about atomic nuclei, but what little they do know has made possible the atomic bomb, nuclear reactors, and radioisotopes What additional wonders may be hidden in the tiny hearts of atoms no one today can even guess

Most scientists now agree that the basic building blocks of an atomic nucleus are the particles of matter called protons and neutrons Both are about two thousand times heavier than an electron, but are still incredibly small They differ in that the proton bears a positive charge and the neutron has no charge at all It is the protons in a nucleus that give it its positive charge and cause it to attract and hold in their orbits the electron planets which go to

make up the outer portions of an atom In a normal atom there is always one electron planet for each proton in the nucleus

Both of these particles are enormously important The number of protons in a nucleus, for example, determines the kind of chemical substance the atom is The number of neutrons, together with the number of protons, determines the weight of the atom and therefore the isotope it is Neutrons also determine the atom's stability Thus, if there are too many or too few neutrons in relation to the number of protons present, the nucleus may spontaneously throw out a small charged particle or two as it adjusts itself to a more stable combination Atoms which do this are said to be radioactive, and each time they emit a particle they change into an entirely different kind of material Radium, the most plentiful radioactive element in nature, will do this a number of times at highly irregular intervals over the course of many thousands of years, ultimately becoming lead, which is stable

The simplest atom in existence is that of ordinary hydrogen gas—the lightest element on earth—which consists of but one proton as the nucleus and one electron planet It is the only atom which has no neutrons at all in its nucleus If you were to take an ordinary hydrogen nucleus and add a neutron to it, you would have a substance known as "heavy hydrogen," or deuterium, which is the ingredient in heavy water that makes it heavier than normal water Heavy hydrogen, although it weighs more than ordinary hydrogen, is still hydrogen, however, because it still has but one proton in its nucleus If you were to add another proton to heavy hydrogen you would have a rare kind of helium

The biggest and most complicated atom in nature is that of ordinary uranium metal, which contains 92 protons and 146 neutrons bound tightly together in the nucleus This metal, because it contains 238 particles in its

atomic nuclei (the sum of 92 protons and 146 neutrons), is called uranium-238, or frequently, U-238. Uranium that has only 143 neutrons is called U-235, the sum of 92 and 143. One of the central mysteries of the atomic energy science is why the protons, which all bear a similar electrical charge, remain tightly cemented together in the nuclei of atoms as big as those of uranium.

In between the extremes of hydrogen and uranium there is a wide variety of combinations of protons and neutrons which go to make up the atoms of all the substances of the earth. Thus, oxygen has 8 protons and 8 neutrons, gold 79 protons and 118 neutrons, and lead 82 protons and 125 neutrons.

In radioactive atoms the very tiny particle that is thrown out of the nucleus as the atom changes into something else is frequently an electron. And yet, you will recall, electrons were not mentioned when we were discussing the basic building blocks of atomic nuclei. If you are wondering where these electrons come from, so, indeed, are the scientists. This is just one indication, and there are many more, that atomic nuclei are vastly more complicated and mysterious than many scientists had at first assumed.

Electrons are not the only particles of matter ejected by radioactive atoms. Some—the bigger and heavier ones like radium—emit much larger particles composed of two protons and two neutrons tightly cemented together. These are called "alpha particles," and they are really nothing more nor less than the nuclei of helium atoms. The electrons emitted by radioactive atoms are called "beta particles." There is also a third type of nuclear radiation called "gamma rays." These, according to current theory, are not particles at all. They are simply pure electromagnetic energy, as is light or X rays. All, however, are dangerous to humans because they will destroy the cells which make up the tissues of the body.

In more recent years, in addition to the proton, neutron, and electron, a number of other sub atomic particles have been discovered These bear such names as the positron, the neutrino, and the meson, of which there are several types The more man has been able to find out about these particles, the more he has realized that he really doesn't know very much about them For this reason, important research efforts both in this country and abroad are being mounted to explore their mysteries for clues to the real nature of the atomic nucleus and what holds it together so firmly Many scientists think the recently discovered meson—a particle intermediate in weight between an electron and a proton—holds the key to these nuclear secrets

Most of the research into the nature of atomic nuclei is done with cosmic rays or with giant atom-smashing machines with names like Van de Graaff generators, linear accelerators, cyclotrons, synchrotrons, betatrons, cosmotrons, and bevatrons Cosmic rays are useful because they consist of electrically charged particles (current theory holds that most of them are probably protons) that fly into the earth's atmosphere from outer space No one knows where they come from or why But they come at enormous speeds and when they strike the nuclei of the atoms which go to make up the atmosphere they smash them, causing such particles as mesons to fly out These particles, because they bear electric charges, will make an identifiable track in photographic film, and can be detected by this means Also useful are such instruments as the Wilson cloud chamber, which is a box containing air highly saturated with moisture, as in a cloud When a charged particle passes through this artificial cloud it will leave a track, much like the vapor trail of a high-flying airplane, which can be seen and photographed Particles of different speeds and sizes can be identified in this manner It was, in fact, the way in which the meson was discovered

To work with cosmic rays, however, means organizing mountain-climbing expeditions or the use of high-flying aircraft or rockets. Even then the results cannot be very satisfactory because of the great difficulty in maintaining controlled conditions and in taking complicated equipment to the required altitudes.

Much more satisfactory are the atom smashers which are now very prevalent in the government and university laboratories of this country, due mainly to the efforts of the Navy Department and the Atomic Energy Commission. At present, eighty-seven such machines are supported entirely or in part by the Atomic Energy Commission. Of these, the two largest are the bevatron at the Radiation Laboratory of the University of California at Berkeley and the cosmotron at the Brookhaven National Laboratory on Long Island.

So important are these particle-accelerating machines in the atomic scheme of things that I believe it would be useful to take a moment to explain roughly how they work. Let us assume we wish to accelerate protons. You will recall that a single proton constitutes the nucleus of ordinary hydrogen gas. It is therefore fairly easy to obtain a plentiful supply of protons by simply buying some hydrogen gas from a chemical supply house. But in normal hydrogen gas the protons come as parts of atoms, complete with accompanying electrons. Our first job is to get rid of these electrons. We are helped in this by the fact that some metals, such as tungsten, release electrons when they are heated. Thus, if we pass our hydrogen gas into a chamber containing a heated tungsten wire, the electrons being released by the tungsten will knock the electrons out of the atoms of hydrogen gas, leaving only the proton nuclei. The gas is now said to be ionized, or electrically charged.

Once ionized, the gas is allowed to diffuse upward into the particle accelerator. If the accelerator is a cyclotron,

it is essentially a giant cake-shaped, hollow magnet, split vertically down the middle into two parts called "dees" Protons enter the machine in the space between the two dees At the time of entry, one of the dees is positively charged and the other negatively charged The positive dee repels the proton and the negative one attracts it. Thus begins the proton's acceleration But hardly does it get under way before the charge in the dees is reversed This starts the proton on a circular course inside the cyclotron In the 184-inch (the diameter of the 4,000-ton magnet) cyclotron at Berkeley the charge in the two dees is reversed at a rate of 20 million times a second, causing the particle to pick up speed swiftly as it travels in an ever-widening circle within the machine Particles make 10,000 revolutions in a thousandth of a second and emerge at a speed which is nearly half that of light When they leave the cyclotron they are pointed at a target material containing the atoms to be smashed The fragments of the resulting collisions are then studied for clues as to the nature of the nucleus The first artificially produced mesons were made in the 184-inch cyclotron in this way in 1947

The other principal particles accelerated in atom smashers are deuterons, alpha particles, and electrons Deuterons (nuclei of heavy hydrogen atoms) and alpha particles (nuclei of helium atoms) can be obtained and accelerated in the same way as protons The techniques with electrons are somewhat different, not only because they are negatively rather than positively charged, but also because they are much lighter in weight than other nuclear particles

Interestingly, in accordance with Einstein's theory of the equivalence of mass and energy, the faster a particle is accelerated the larger it becomes Thus, an electron accelerated to an energy of 300 million electron volts (300 MEV), which brings it up to 99 99 per cent of the speed

of light, will increase in mass 600 times A proton, being much heavier, will increase only about 30 per cent in mass

Until recently the largest and most powerful particle accelerator in the world was the 184-inch Berkeley cyclotron, which can operate in the 200 to 400 million volt range Last year, however, a new machine, called the cosmotron, went into operation at the Brookhaven National Laboratory which can accelerate protons to energies of 2 5 billion volts or more It is called the cosmotron because in it man, for the first time, is able to impart energies to nuclear particles that are equivalent to those of cosmic rays Now nearly completed at Berkeley is still a larger machine, the bevatron, which is expected to achieve energies in the 5 to 6 billion volt range, thus opening up a whole new area to the scientists who probe the mysteries of the nucleus

The two main centers for this kind of work in the United States are the Berkeley Radiation Laboratory and the Brookhaven National Laboratory The Berkeley Laboratory sits high on a hill behind the campus of the University of California and looks out over San Francisco Bay In many ways it is fair to say that this is the world center of particle-accelerator work The laboratory was established in 1936, and its work is directed by Dr Ernest O Lawrence, the inventor of the cyclotron Among the many proud 'firsts" it has achieved with its unique equipment, in addition to the first artificial production of the meson, are the development of the electromagnetic process for the production of U-235, the discovery of plutonium, the first production of plutonium, and the discovery of the new man-made elements neptunium, americium, curium, berkelium, and californium

The Brookhaven National Laboratory, which is much newer than Berkeley, having been built since the end of the war, is located on Long Island about seventy miles from New York on the site of the Army's old Camp Upton

It is the same site that Irving Berlin made famous in a musical review during World War I when it was known as Camp Yaphank. Brookhaven today still possesses many of the features of a well-kept Army post with its many barracks-type buildings and its spaciousness. Among its newest features are the modernistic frame cosmotron building and the large yellow brick and glass structure which houses the Brookhaven research reactor described in Chapter VIII. None of Brookhaven's staff of about 1,100 lives on the laboratory site itself, although some of the dormitories there are used by visiting scientists who come in from surrounding institutions to use the reactor or other of the laboratory's unique research equipment. The only commercial enterprises on the site are a store and a cafeteria. Besides the reactor and cosmotron, Brookhaven also has well rounded facilities for research in biology, medicine, physics, and chemistry. The laboratory is operated by a non-profit corporation composed of nine northeastern universities.

In addition to Berkeley and Brookhaven, the major centers of Commission-sponsored research with high-energy atom smashers are Carnegie Tech, the University of Chicago, Columbia, the University of Rochester, Cal Tech, Cornell, M.I.T., the University of Michigan, Purdue, the University of Illinois, and Stanford. In all, the Commission spends about $7,500,000 per year on these projects.

But the quest for more and more atomic knowledge is not limited to atom smashing and the probing of nuclei. Scientists also want to learn all they can about the already discovered fission process, its products, and the effect of these products on humans, animals, plants, and materials.

The atomic energy program as it exists today is built on the fact that the atomic nuclei of a rare isotope of uranium, U-235, will fission, or split in two, when they are struck by free neutrons, and that they will release other

neutrons in the process So far in this book, we have mentioned this fission process a number of times, but we have not discussed just how it works So let us consider the nucleus of an atom of U-235 It has 92 protons and 143 neutrons Although this nucleus is radioactive, it is so slightly radioactive that it would take four million years for half of a given quantity of U-235 to emit nuclear radiations and change into something else For most intents and purposes, then, it can be considered as stable, and it is as hard to smash as any other atom—that is, unless it is struck by a neutron Then the result is quite different For some reason but little understood, the nucleus of a U-235 atom will fly apart violently into two approximately equal parts when a neutron is introduced This is the process called fission

The products of fission are kinetic energy, nuclear radiation, two new highly radioactive atoms about half the size of the U-235 atom, and an average of two and a half new neutrons Kinetic energy is the energy possessed by bodies in motion In the case of fission, it is the energy possessed by the two atomic fragments that fly apart at very high speeds As these fragments lose their great speed through collisions with other atoms, this kinetic energy is transformed into great quantities of heat

If neutrons were not released, however, the fission process in U-235 would not be significant The atoms of most substances can be made to split in two if struck by neutrons traveling at just the right speeds, but unless new neutrons are produced, that is where the reaction stops With U-235, however, the neutrons that are released by one fission go on to strike other nuclei and, if enough U-235 is present to absorb a substantial share of these neutrons, a nuclear chain reaction develops If this chain reaction is allowed to proceed uncontrolled, an enormous explosion, such as that produced by an atomic bomb, will

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oratory near Santa Fe, New Mexico, operated for the Commission by the University of California

The Los Alamos Laboratory is situated on a series of mesas, separated by deep canyons, on the eastern side of the Jemez Mountains, where they slope downward into the Rio Grande Valley Across the valley is the crimson outline of the Sangré de Cristo ("Blood of Christ") range Santa Fe is thirty-five miles to the southeast Because of its security-enforced isolation, the laboratory has its own town, also called Los Alamos The town is 7,300 feet above sea level and 2,000 feet above the nearby Rio Grande It is reached by a road hewn out of the sheer face of an enormous cliff There are no railroads to Los Alamos, but it has its own airport It also has its own movies, hotel, stores, modern apartments, golf course, and quiet residential areas, much like those of any other American city Most of the architecture is adobe, in keeping with the Indian-country setting

It is here that the men and women who design and develop atomic weapons live and work Their lives are much like those of people everywhere They work normal hours, their children go to good public schools, they attend church on Sundays, they belong to such groups as the Kiwanis and American Legion, and they make frequent trips to the nearby mountains for fishing and hunting or to the nearby valley to visit the Indian pueblos that dot northern New Mexico Occasionally the men of the town go off on business trips to Berkeley or New York or Chicago for scientific meetings, to Washington or Albuquerque for conferences, or to the Las Vegas Proving Ground or Eniwetok for field tests of the weapons they develop There is one striking difference between their town and most other American cities you must go through a guarded gate to enter it, and casual visitors are not welcome Of the three Commission towns, Los Alamos is the only one that is still closed

result If, on the other hand, the reaction is restrained by the use of some neutron absorbing material such as cadmium, it will proceed slowly, as in a nuclear reactor

Unfortunately, U-235 is very rare, comprising but one part in each 140 parts of uranium as it occurs in nature Virtually all the rest of natural uranium is U-238, which will not sustain a fission chain reaction Fortunately, however, U-238 can be changed into the man-made element plutonium, which will This transmutation is accomplished by striking the nucleus of a U-238 atom with a neutron It works this way When a neutron is absorbed into a U-238 nucleus, the U-238 atom becomes U-239, which is very highly radioactive It very quickly throws out an electron, changing in the process into the artificial element neptunium, which has 93 protons and 146 neutrons This, too, is highly radioactive and in a very short time emits another electron, changing into plutonium, with 94 protons and 145 neutrons Thus it is possible to make fissionable plutonium from non-fissionable U-238 by exposing a quantity of U-238 to the neutrons produced in a fission chain reaction in U-235 This, in fact, is precisely what is done in the Hanford reactors

There is also one other man-made material capable of sustaining a fission chain reaction This is U-233, which can be made from the metal thorium in much the same way as plutonium can be made from U-238, in other words, with neutrons Although U-233 is not yet in wide use, it probably will be as time goes on

The effort to learn more about the fission process and how to put it to work is being carried on in literally hundreds of laboratories in all parts of the country Out of a total budget this fiscal year (1954) of about one billion dollars, something over one hundred million is being spent on this effort At present, perhaps the most important such work is being carried on in the field of weapons, and the center of this research is the Los Alamos Scientific Lab

be put to work is in the production of power, discussed in Chapters VIII and IX One of the main centers of this kind of research is the Argonne National Laboratory at Lemont, Illinois, on the outskirts of Chicago Argonne is the successor to the famed Metallurgical Project of World War II which built the first nuclear chain reactor The laboratory is operated for the Commission by the University of Chicago and is under the direction of one of the world's foremost reactor scientists, Dr Walter H Zinn Thirty-two educational institutions and research laboratories in twelve midwestern states are affiliated with Argonne and maintain research and training programs in co-operation with it

The Argonne Laboratory occupies a newly built home which replaces the makeshift facilities used by the Metallurgical Project during the war These were located in a score or so of temporary locations scattered in and around Chicago The laboratory today, which occupies a rural site about twenty-five miles west of downtown Chicago, looks much like many well-kept industrial laboratories, with its low-lying red brick buildings and wide lawns None of the laboratory's staff of about 2,000 lives on the fenced-in site Many of them live in the quiet village of Lemont, while many others commute daily from Chicago and its suburbs

In the years since the war, Argonne has maintained its pre-eminence in the reactor field Among other things, it designed and operates the Experimental Breeder Reactor which first produced usable electrical power and which first demonstrated the feasibility of breeding It also performed the basic design and development work on the first atomic power plant for submarine propulsion, and assisted with the design of the production reactors at the Savannah River plant in South Carolina

Another important center of reactor research and development work is the Oak Ridge National Laboratory

During the war, Los Alamos was known simply as "Post Office Box 1663, Santa Fe" Its existence was not made public until after the Hiroshima explosion In its wartime days it was a mecca for many of the most brilliant scientists of the free world men like Enrico Fermi, Bruno Rossi, Edward Teller, John von Neumann, Hans Bethe, Niels Bohr, Cyril Smith, and Sir James Chadwick Some were refugees from European dictatorships who had sought safety and a chance to fight for freedom in America, some were members of the British Scientific Mission, some were native born Americans

Since the war, the town of Los Alamos has been largely rebuilt and greatly expanded It now has a population of about 13,000 The laboratory, which during the war consisted of hastily built temporary structures, has also been partly rebuilt and enlarged For the past several years the laboratory has been under the very capable direction of another of America's great scientists, Dr Norris Bradbury, and the staff is composed totally of American citizens, the British Scientific Mission and other non-citizens having left in 1946 It is these people who are working to design and develop ever more efficient weapons in an ever wider variety of shapes and sizes In recent years they have added work with fusion to their earlier work with fission alone Whereas fission is the splitting of heavy atoms, fusion is the combining of lighter ones, such as hydrogen Both processes release enormous amounts of energy In fact, it is the fusion process which produces the energy that comes to us from the sun Although the work at Los Alamos with fusion is for the purpose of developing H-bombs, it is also valuable basic research in a field heretofore but little understood If there are any peaceful uses in the fusion (also called thermonuclear) reaction, the work being performed at Los Alamos will certainly aid in revealing them

Another important way in which the fission process can

mission Radioisotope Training Program By 1953 more than 700 people from some 400 different institutions in the country and abroad had taken one of the six four-week courses offered by the Institute each year The Radioisotope Training Program has been a real help to the rapid rate at which the use of isotopes has increased throughout the free world

Other leading centers of reactor research and development work, in addition to Oak Ridge and Argonne, are the Bettis Laboratory at Pittsburgh, Pennsylvania, which is operated for the Commission by the Westinghouse Electric Corporation, and the Knolls Atomic Power Laboratory at Schenectady, New York, which is operated by the General Electric Company Both of these are leaders in the propulsion reactor field

Although reactor work is carried on at a number of government-owned laboratories and private industrial concerns in various parts of the country, most of the full-scale reactors are being built at the Commission's National Reactor Testing Station in Idaho This remote 400,000-acre reservation is the home of the land-based prototype of the first submarine reactor, the Materials Testing Reactor (operated by the Phillips Petroleum Company), and the Experimental Breeder Reactor Test facilities are now under construction there for use in the development of the first atomic aircraft engine It also has a large plant for processing the fuel elements of the various reactors which are now located there or will be in the future Its employees commute daily from Idaho Falls, about fifty miles across open country to the east In many ways, the Reactor Testing Station serves the same purpose in the field of reactors as do the Nevada and Eniwetok Proving Grounds in the field of weapons

There is much more to the effort to learn about fission and to put it to work than the development of weapons and power reactors, however Behind these programs, and

at Oak Ridge, Tennessee It is operated for the Commission by the Union Carbide and Carbon Corporation, as are the gaseous-diffusion plants located on the Oak Ridge reservation Like Los Alamos, the Oak Ridge Laboratory has its own town, where most of its 3,000 employees live

The Oak Ridge National Laboratory is located in a valley away from the town Its main building is large, new, and severely functional This would be the administrative center of the Oak Ridge Laboratory and also the home of much of its technical equipment Surrounding this new headquarters are a number of smaller, shedlike structures containing, among other facilities, experimental models of new types of reactors, such as the Homogeneous Reactor Experiment discussed in Chapter VIII Oak Ridge is also a center of research work leading to the development of an atomic engine for aircraft

The largest building on the laboratory grounds outside of the headquarters houses the world-famed Oak Ridge reactor, producer of most of the radioisotopes that are shipped by the Atomic Energy Commission to all corners of the United States and the free world Near the reactor itself is the distribution center for the radioisotope program, where the isotopes are separated, packaged, and shipped

In addition to its many research, development, and production activities, Oak Ridge also is a major training center in the atomic energy field It is, for example, the home of the Atomic Energy Commission's Reactor Training School It is also the headquarters of the Oak Ridge Institute of Nuclear Studies, an organization of thirty leading universities in fourteen southern states, the District of Columbia, and Puerto Rico The Institute operates several fellowship programs in atomic energy, arranges for faculty members of its associated institutions to perform research work with the Oak Ridge Laboratory's specialized equipment, and carries out the Atomic Energy Com-

constructed a fifty-bed cancer research hospital on the campus of the University of Chicago The hospital is operated by the Argonne National Laboratory It uses radioisotopes from the Argonne reactors and has many unique facilities, including a betatron that can be used to apply beta rays directly to cancerous tissues Other cancer facilities are located at Brookhaven and Oak Ridge The patients admitted to these hospitals come there on the recommendation of their physicians after all other treatments have failed Work on these cases is adding substantially to the knowledge of the nature of cancer and the methods of treating it Although it would be impossible to say that a cancer "cure" has been developed through atomic energy, it is fair to say that the lives of many patients have been lengthened and made more comfortable through treatment with nuclear radiations

Other important medical research laboratories of the atomic energy program are located at the University of Rochester, New York, the University of California at Los Angeles, and the University of California at Berkeley In addition, the Commission supports biological and medical research in several hundred universities and hospitals throughout the country

Of all the problems facing the Atomic Energy Commission, one of the most difficult is to determine just the right amount that should be spent each year on research efforts of the type described in this chapter Recently a Congressman suggested that the Commission divide its research projects into three categories those sure to pay off, those likely to pay off, and those unlikely to pay off This simply cannot be done, and it would be dangerous to attempt it Yet there must be some intelligent way to determine what should be spent on this kind of activity and how Although it is probably impossible to produce a precise yardstick, there are a few facts and principles which I believe can and should serve as effective guides

in support of them, literally thousands of research projects in physics, chemistry, metallurgy, biology, and medicine are under way in government laboratories, universities, and private research institutions in all parts of the country In the field of metallurgy one of the leading centers is the Ames Laboratory, owned largely by the government and operated by Iowa State College in Ames It was this laboratory that developed the wartime process for producing pure uranium metal The laboratory actually produced with its own equipment a substantial part of the uranium that was used in the first reactor built by Enrico Fermi

Of all of the areas of atomic energy research, the one with perhaps the most direct and personal effect on mankind is that of biology and medicine The atomic energy program annually spends something over $20,000,000 a year on this kind of research It ranges all the way from studies of the survivors of the atomic bomb attacks on Hiroshima and Nagasaki to research with successive generations of fruit flies that have been exposed to nuclear radiation One of the principal interests of the Atomic Energy Commission in this field is to protect atomic energy workers from the harmful effects of nuclear radiations It is a source of real pride to the Commission that not one life has been lost because of overexposure to nuclear radiation since the Commission took over the atomic energy program some six years ago

But this is only one of the Commission's medical responsibilities Equally important is the utilization of nuclear radiations in the betterment of man's health As one example, there is cancer Nuclear radiations and cancer are very closely related Radiations can cause cancer, help detect cancer, kill cancer, and help in gaining an understanding of cancer

In an effort to learn all that nuclear radiation can do in the war against cancer the Commission has recently

at best merely chipped them Yet there is every reason to believe that the forces that work within the nucleus of an atom are as varied and complex as the many forces which cause our earth and the forms of life upon it to ebb and flow, to live and die

The third principle is that the machines with which man explores the inner universe of the atom are very costly, and that the government must foot the largest share of the bill to construct and operate them When we speak of an atomic energy laboratory, such as Argonne or Oak Ridge, we are speaking not simply of a laboratory as we knew it in high school or college, with its racks of test tubes, its intestinal-shaped mazes of glassware, and the ever-present and unpleasant odor of hydrogen sulphide We are speaking of equipment such as the cosmotron at Brookhaven, which cost four million dollars to build, the bevatron at Berkeley which will cost nine million, and the Brookhaven reactor which cost twenty-five million We are speaking of laboratories which have annual operating budgets of many millions of dollars and which cost tens of millions of dollars to build These are not the kind of facilities that university or private foundations can support This fact, then, must be considered when we decide how much shall go to the support of these government-built laboratories

The fourth principle I would like to see recognized is that a very large percentage of both basic and applied research should be conducted, not in the great national laboratories of the Atomic Energy Commission or in industry, but in our colleges and universities The Atomic Energy Commission now provides about $20,000,000 annually for this work This respresents one of the greatest financial assists which the colleges of this country have ever enjoyed, and one of the finest sources of talent available to the atomic energy program Some educators have decried this trend and with some justification, for it has

First is the principle that basic research (the quest for pure knowledge) must be treated with the same dignity and given the same encouragement as applied research (work toward a specific goal), and that there must be a healthy balance between the two Some people are inclined to regard basic research as interesting but unproductive, aimless rather than responsible, academic rather than practical, a luxury rather than a necessity It is easy to slip into this frame of mind The physicist who is attempting to determine the nature of a meson is less likely to intrigue a layman than the scientists studying woods which are most likely to resist termites But who can tell which is more likely to produce the more significant results? Research, by definition, is the exploration of the unknown Yet if the area be unexplored or unknown, who is wise enough to predict what will come out of it? It is true that some research can be irresponsible, some of it can be little more than a "boondoggle But whether it is a boondoggle depends not upon whether it is basic or applied, it depends upon the technical ability, integrity, and perseverance of the researcher *The simple historical fact is* that the great atomic energy program of this country was produced almost overnight from the undramatic and unsung research work of the 1930's

The second principle upon which I should like to see agreement is that, in the field of nuclear physics and its related sciences, we are in an area which is largely unknown, unexplored, and amazingly devoid of basic information It is incredible but true that much of the atomic energy program is devoted to splitting atoms and reaping the product thereof for bombs, and yet we still know very little concerning the nucleus of the atom we split

Yes, the scientists have identified the electron, the proton, the neutron, and more recently the meson But this is only the beginning With all of our atom-smashing paraphernalia, we have never really smashed atoms! We have

CHAPTER *xii*

Secrecy, Security, and Spies

SECURITY and secrecy are not synonymous The first is an ultimate objective of the country, the latter simply one method used, and sometimes abused, in achieving it

Security is the broad aim of the atomic energy program, and it means more, far more, than just the careful handling of documents, the adequacy of safes or fences, and the protection of the program against spies, saboteurs, and fools

The Atomic Energy Act of 1946, the basic law under which the Atomic Energy Commission operates, states that the development and utilization of atomic energy shall be carried on "subject at all times to the paramount objective of assuring the common defense and security"

The Act is speaking here of security in the broad sense—as a synonym for strength and stability Thus interpreted, it becomes a directive to the Commission to operate with such enterprise, such encouragement of new ideas, and such imagination and boldness that the United States shall remain far out in front in the prosecution of atomic research, the acquisition of uranium ores, and the production of feed materials, fissionable materials, and weapons

Security in this broad sense, therefore, is the Commis-

within itself the potential of government domination or control of academic pursuits But, good or bad, the economic facts of life in our time dictate the partial dependence of universities upon state or federal funds for support of research There is no good evidence that a change can be anticipated Both the government and the citizen must always be on guard, however, to make sure that its assistance never becomes an instrument of dominance Grants should go where technically capable people are located, and, once awarded, there should be the least possible dictation as to how the research is done

A fifth principle which must be considered before one can intelligently determine the level of support for research in the atomic field is that progress in science recognizes no international boundaries or special environments Attempts to monopolize it are inevitably in vain, and the greatest progress can be made only by the free exchange of information We shall never keep our leadership in the international scene by attempting to hold a basic fact of nature behind a cloak of secrecy We can keep our leadership only by relying upon our ingenuity, our engineering skill, our know-how, and our productive capacity to turn up new knowledge and put it to work I hope we shall never, under the slogan "economy" or under the notion that we must "go practical," so cut back our basic research program in this country as to lose our current but tenuous lead in the area of fundamental research "Secrets" alone will never hold our lead for us—achievement is what is needed

ties, which would strengthen the atomic might of an unfriendly power In World War II we sought to keep this information from a Germany that had launched upon an atomic energy program of her own Today we seek, in the final analysis, to keep such information from the Soviet Union—and with very good reason

The obvious way, then, by which the decision to keep something secret can be made is to ask the question "Will the release of this information substantially advance a potential rival?" If the answer is "yes," then it would appear that the "secret stamp" should be applied But there is another question that must be asked, too, and that is "Will keeping this information secret result in a substantial retarding of our own progress?" If the answer is again "yes," then the decision becomes one of balance "Will the Russian program be advanced more than ours by the release of this information?"

As you can see, decisions of this sort are, to a large degree, matters of judgment, and often little more than informed guesswork But one thing is certain Every time America decides to keep something secret we are running the risk of slowing our own progress by severely narrowing the range of skills and experience that can be brought to bear on the problems involved It is just possible, I believe, that in our security policy we have often been so sure that secrecy meant safety, and so determined to tie the hands of a potential enemy, that we have on at least some occasions tied our own This is the risk of secrecy But it is a calculated risk that we must continue to take, as carefully and as intelligently as we can, for at least as long as we have reason to believe that we are ahead of our competitors

Roughly, atomic security falls into three main parts First, personnel security—the protection of the program against untrustworthy people, second, physical security—the protection of our plants and laboratories against sabo-

sion's responsibility But security in the narrower sense—the protection of our secrets from theft and our property from harm—deserves a chapter in this book because it is one important means by which we try to achieve total security, and because one out of every four employees in the Atomic Energy Commission, one out of every twenty five of our contractors' employees, and probably as much as one out of every twenty dollars spent on operation of the atomic energy program are devoted in one way or another to maintaining it In addition, last year it required about 325 man years of investigatory work on the part of the Federal Bureau of Investigation

More has been said and written on this subject of atomic security than on almost any other phase of the atomic energy program But much of it is quite worthless in solving the problem of how tight or loose security should be, what price we must pay or can afford to pay for it, and, more importantly, at what specific points in our program it should be applied

The abstract discussions about the good or evil of security that one generally hears are rather meaningless, so far as the central question that daily faces the Commission is concerned The question is simply this Precisely what are we trying to keep secure, why, and at what cost?

Unfortunately, the specifics are difficult to discuss publicly, for to describe the things the Commission feels should be denied to a potential enemy is to identify for him the very areas about which he wants most to know—such as where the United States has developed a special proficiency or licked a particularly tough problem at great cost and with significant results It has been said, and rightly so, that 'he who admits the possession of a secret has already half revealed it

In general, however, what the Commission is trying to do with its security program is to protect that information developed in the laboratories and processing facili-

people who are considered to be bad security risks for any of the following reasons

1 *Disloyalty*

This includes spies, traitors, saboteurs, Communists, Fascists, subversives of all sorts, and those who have objected to military service for other than religious reasons

2 *Bad or irresponsible character*

This includes criminals, alcoholics, drug addicts, homosexuals, the insane, the dishonest, those who have demonstrated a habitual disregard for security regulations, and those who have falsified security questionnaires

3 *Bad or dangerous associations*

This includes those who have established a close association with spies, traitors, subversives, or agents of unfriendly governments, or who might be subject to threats or blackmail because close relatives reside in areas controlled by unfriendly governments

The Commission was the first agency to set forth in its security criteria that no one could be employed who was a homosexual A few managed to slide by in the selection process, but they have been fired as soon as discovered From one of these I learned how wise was our rule

"Never," he said, "permit a homosexual in the program The opportunities for blackmail are too great I have never been approached by a blackmailer, but I have feared what I would do if I had been Don't let them in, Mr Chairman'

I know there are some people who sincerely question the fairness of our exclusion of people because of their associations Is this, then, really a fair consideration? Were not many very good people associated in the late 1930's with organizations which at the time were nothing more than leftist or liberal? Obviously this is the case Association evidence must therefore be very carefully evaluated, and the Commission tries very hard to do this It has, for example, followed these principles in such evaluations

tage, theft, and vandalism, and third, document security—the protection of our secret papers against theft and unfriendly eyes

Personnel security poses the most difficult problem of all—how to keep even a single rotten apple from entering the AEC barrel So far the Commission has been fortunate Since the civilian Commission assumed its duties in January 1947, no person in the program has been charged with disloyalty, much less arrested, indicted, or convicted Those persons, such as Fuchs, Greenglass, Gold, and the Rosenbergs, brought to the bar of justice in recent years, were wartime operatives whose crimes were not discovered until much later

In spite of every precaution the Commission may take, however, the law of averages suggests very strongly that somewhere in its vast program a traitor may appear What precisely, then, is being done to prevent this?

First of all, the law requires that every employee of the Commission, and every employee of the Commission's contractors who has access to restricted data (information relating to the production of fissionable material and the making of weapons), shall be investigated by the Federal Bureau of Investigation, or by the new investigatory office of the Civil Service Commission, as to his character, his associations, and his loyalty Each of these investigations takes from 55 to 100 days, depending upon the background of the prospective employee, and each costs an average of about $200 In fiscal year 1952 there were nearly 90,000 such investigations, and when the files were examined by the AEC s security people about one per cent of the persons involved in these cases were denied employment because of derogatory information that was turned up

The Commission early set up its own criteria for the selection of people for employment in the atomic energy program In general, these criteria are designed to exclude

so, nothing in his deportment, short of his actual physical contacts with Russian agents—which could have been discovered only by constant shadowing of him—would have raised the slightest suspicion.

Klaus Fuchs was a serious-minded bachelor, detached, retiring, shy, displaying little humor. While at Los Alamos he was much sought after as a baby sitter. He was unusually competent in his field, a distinguished theoretical physicist who talked little of politics and world problems. He was neither very much liked nor disliked, and he was actually not very well known to his colleagues.

Klaus Fuchs was a perfectionist, contemptuous of those who were not. Interestingly enough, he was outwardly conscientious when it came to security matters, and in declassification conferences he took a fairly conservative attitude toward the release of technical information to the public. He was meticulous in the handling of secret documents and in maintaining high security standards in his own office. He had a methodical brain, and he possessed a high degree of self-composure. Superficially he appeared to be one who abided by all of the rules of the game—the rules of the laboratory, the rules of the office—but basically he was beholden only to his own conscience.

But how was anyone to know what that conscience dictated? What made it tick? How, under any possible investigative procedure, could a revolutionary with such a conscience be spotted?

To illustrate further the difficulty of detecting the most dangerous traitors and spies, let us look at the case of Bruno Pontecorvo, onetime physicist in the Canadian project in Toronto during the war, and from 1949 until recently one of the top theoretical physicists at the Harwell Laboratory in England.

It may be recalled that Pontecorvo, on a sudden flight from Rome to Helsinki, via Stockholm, disappeared with

1 When an individual has become identified with an organization established as a "front" for subversive interests, the personal views of the individual must be shown to coincide with or be sympathetic to the subversive line of the sponsor

2 When an individual is identified with an organization *known to be infiltrated by members of subversive groups*, there must also be evidence that the individual is a part of or sympathetic to the infiltrating element

3 When the close relative of an individual lives in a country controlled by an unfriendly government, the case must be carefully evaluated in the light of the risk that possible pressure could force the individual to reveal secret information or perform an act of sabotage

4 When an individual has established an association with friends, relatives, or other associates who have subversive interests and associations, the association must be shown to be "close and continuing This means the individual must live on the same premises as his associate, or visit him frequently, or communicate with him frequently by other means

But what meaning, one may well ask, would these measurements have had in the case of Klaus Fuchs, the master traitor, who, back in the early 1940s, came into the wartime program with the United Kingdom scientific team, certified as having the highest clearance of that country? If the present procedures, including the FBI investigation, had been in effect then, what would have happened? It is hard to say He might, and he might not, have been allowed to participate This is arguable He would probably have been suspect, in a way, for an investigation of his background in Germany, where he had Communist affiliations, would have raised a question

Now let us assume for a moment that this question might be passed and that he would have been cleared If

detected by a clever diagnostician, or guarded against by the erection of steel fences and the employment of guards who know how to frustrate their unreasoning plots These are the 'blunt" fanatics, and their very bluntness gives them away

Also easier to spot are the vocal ideological types who for one reason or another are detractors of our democratic institutions but who, unlike the fanatic, simply want an outlet, an opportunity to speak, and most of all an audience For these people the Hyde Park treatment and a soapbox audience usually suffice It is in this group that we find many of the association cases—the joiners of front organizations—and the question is always "Is he simply a joiner or a well-motivated reformer, or is he, on the other hand, something more dangerous, a potential Fuchs?" Although it is often hard to determine the real motives of these people, it is not hard to discover them

The mechanics for locating an undesirable are essentially these

Before anyone may secure a clearance from the Commission for access to classified atomic information he must first fill out a Personnel Security Questionnaire, a "PSQ" This is a form which contains some score or more questions, covering such topics as membership in Communist organizations A lie here could mean a perjury prosecution One therefore hesitates to lie

Next comes the background investigation by the FBI This includes a check of the individual s file, if any, in FBI headquarters and other law-enforcement agencies, together with an intensive investigation by FBI field agents into all of the past associations of the individual, including interviews with people who have known him Under a recent change in the law, a substantial number of these investigations will be conducted by a new investigatory office set up in the Civil Service Commission, but the FBI will continue to do a large share of the work, particularly

his wife and two children, probably behind the Iron Curtain He was presumably motivated by a desire to assist the Russian atomic energy project

Bruno Pontecorvo was an entirely different type of personality from Fuchs, but one that would perhaps be even more difficult to detect in any investigative procedure He was a man with a complete absence of fanaticism and moral gloom Unlike the mousy, retiring Fuchs, Pontecorvo was an extrovert He was carefree, gregarious, handsome, and athletic And at the same time he was an able, respected, and imaginative scientist A thorough investigation of Pontecorvo's background would have revealed something that he never particularly tried to hide, namely, that his brother in Italy was a Communist And yet, from his demeanor and from anything he ever said or wrote, one would suspect Bruno Pontecorvo least of all the scientists gathered at Harwell

Different as they may be in personality, both Fuchs and Pontecorvo fall into a category of undesirables which are the most difficult to detect Such people are drawn by an ideology to find that spot from which they can most effectively commit a traitorous act They are smart, they are blessed with education, they are self-controlled No party cards for them, no foolish acts, and no rules and regulations other than the rules and regulations and loyalties of their own creed And yet they will appear superficially to abide by all the rules and regulations of the society in which they live, there is no evidence of the revolutionary in their day-to-day acts

These are the people, of course, who can do us the most harm They are also the people whom we are least likely to suspect Being smart, composed, and plausible, they will quietly seek their place and bide their time

Most of the other categories of dangerous people are easier to guard against—for example, the mentally deranged, the overt fanatic, the assassin These can either be

The harder cases simply do not fall into a clearly black or white area, however Rather they fall into a grey area, and some of them consequently are extremely difficult to evaluate In the final analysis, however, the doubt is resolved in favor of the government, not the applicant, on the theory that government service is not a right that every citizen enjoys, but a privilege Resolving the doubt in this way, however, places a heavy responsibility upon those in the Commission to make a completely fair evaluation, and to see to it that in the process people's reputations are not damaged needlessly

I say this, subscribing fully to the warning of Arthur Schlesinger, Jr

"There are spies and there are victims of gross injustice, the problem is to preserve an atmosphere in which effective judicial determinations as to which is which can be made There is no easy answer to this conflict of principles between civil liberties and national security in the field of government employment The practical results, then, must depend (too much for comfort) upon the restraint and wisdom of individuals If we cannot handle this conflict of principle soberly and responsibly, if we cannot rise to the world crisis, then we lack the qualities of greatness as a nation, and we can expect to pay the price of hysteria or of paralysis Civil liberties do not deny society its right of self-protection They only make sure that this right is used, not to punish dissenters or to flail at nightmares, but to ward off real dangers to the commonwealth"

There are a few persons who are not investigated before they are permitted to have access to secret atomic information These include the President, members of Congress, Presidential appointees, and the agents of the Federal Bureau of Investigation who make the investigations It seems implicit in the law that such people need not be investigated.

where a question arises, or where the individual being investigated will have access to particularly sensitive information

Any derogatory information turned up by the background investigation is evaluated by the security officers of the Commission's field offices, and their recommendation is forwarded to the appropriate AEC field office manager If the manager decides that clearance should be denied, the individual concerned has the right to request a review of his case by a local Personnel Security Review Board composed of persons of the manager's choosing The individual may appear before the Board, may submit evidence to it, and may be represented by counsel if he wishes The local AEC manager then makes a new determination based on the recommendation of this Board If again the clearance is denied, the individual may appeal for another review by the Commission's main Personnel Security Review Board, which is responsible directly to the Commission's General Manager and is composed of leading experts from outside the program After this review the Commission's General Manager makes a determination which is final

In all of its considerations having to do with personnel security cases, the Commission follows this general principle

"The decision as to security clearance is an over-all common-sense judgment, made after consideration of all the relevant information as to whether or not there is risk that the granting of security clearance would endanger the common defense and security If it is determined that the common defense and security will not be endangered, security clearance will be granted, otherwise, security clearance will be denied " *

* Criteria for Determining Eligibility for Personnel Security Clearance," Appendix 8 page 188 Fifth Semi Annual Report of the Atomic Energy Commission to Congress of January 1949

Many of our installations, however, are fenced One of them is the Argonne Laboratory operated for us by the University of Chicago Two years ago a young radio commentator, in search of a story, sat down and wrote one—in advance of the occurrence In lurid detail, and in an effort to demonstrate the laxness of security in the laboratory, he wrote, before the event, a story of his successful attempt to climb the perimeter fence, evade the guards, and enter "the hot area, the special security area, of a vast atomic research project"

He was a little premature The text of his sensational story had to be modified, for as he dropped to the ground after scaling the high barbed perimeter fence he was taken into custody—an ignominious finale to his prank He is, it need scarcely be said, rather fortunate to be alive today

If this prankster had, by some chance, been able to elude the perimeter guards, and if he had been able to elude the other sentries and alarms around the building he wished to enter, he might have made his way to a room where there would have been nothing of a secret nature except that locked securely in heavy metal safes Nevertheless, for public-relations reasons, if for no other, the Commission was quite happy that the fence had been high, that barbed wire had lined the top of it, and that an alert guard had caught the intruder as he dropped to the ground

Physical security of our plants and laboratories is primarily maintained to prevent sabotage where sabotage would be really costly, and to prevent theft of materials and documents of value—much the same reasons why a jeweler bars his windows Bombs in storage and our stores of plutonium and uranium-235 naturally require the highest and the tightest security, for they not only have great value intrinsically, but, once seized, could be turned against us in the form of weapons As we work backward through the production line, therefore, from bombs to fis-

Let's turn now to another phase of security—what we know as "physical security' This has to do with guards and fences and locks How tight should this kind of security be? A sensible answer can only be found by constant examination and re-examination of the question "What's inside the fences, and whom do we want to keep out?"

It is well to remember that some fences have come down The town of Oak Ridge, for example, was until 1949 a "closed city" Today it is as open as New York or Peoria The town of Richland, which houses the people who work at the Hanford plutonium plant, was never a closed city Perhaps someday this same procedure can be followed safely at the other atomic town, Los Alamos, for the new laboratory there, built since the war, is removed from the commercial and residential areas But that time has not yet arrived, for there is still a technical area close to the heart of the town

To illustrate the kind of question with which the Commission is daily faced, it was at one time proposed that the entire Nevada proving-ground area, where atomic weapons are tested, be fenced in This would have called for some 115 miles of fence at a cost of about $200,000 'But why?' we asked 'Is it to keep out Soviet agents?" There are better ways to do this 'Or is it to keep out the curious who might get in the way or be hurt?" The area is posted and it is well patrolled when it needs to be "Or is it to prevent cattle from entering the contaminated area?' The risk of cattle becoming harmed, and the number of such cattle that might be harmed, had to be carefully evaluated, of course, in the light of the cost involved Certainly we did not want to fall into the trap of fencing simply to give the appearance of security, although at times there is a temptation to do exactly that In the end, we did not put up the fence We put up small fences around certain areas, but we determined that the cost of fencing the whole area was not justified

Many of our installations, however, are fenced One of them is the Argonne Laboratory operated for us by the University of Chicago Two years ago a young radio commentator, in search of a story, sat down and wrote one—in advance of the occurrence In lurid detail, and in an effort to demonstrate the laxness of security in the laboratory, he wrote, before the event, a story of his successful attempt to climb the perimeter fence, evade the guards, and enter "the hot area, the special security area, of a vast atomic research project"

He was a little premature The text of his sensational story had to be modified, for as he dropped to the ground after scaling the high barbed perimeter fence he was taken into custody—an ignominious finale to his prank He is, it need scarcely be said, rather fortunate to be alive today

If this prankster had, by some chance, been able to elude the perimeter guards, and if he had been able to elude the other sentries and alarms around the building he wished to enter, he might have made his way to a room where there would have been nothing of a secret nature except that locked securely in heavy metal safes Nevertheless, for public-relations reasons, if for no other, the Commission was quite happy that the fence had been high, that barbed wire had lined the top of it, and that an alert guard had caught the intruder as he dropped to the ground

Physical security of our plants and laboratories is primarily maintained to prevent sabotage where sabotage would be really costly, and to prevent theft of materials and documents of value—much the same reasons why a jeweler bars his windows Bombs in storage and our stores of plutonium and uranium-235 naturally require the highest and the tightest security, for they not only have great value intrinsically, but, once seized, could be turned against us in the form of weapons As we work backward through the production line, therefore, from bombs to fis-

sionable material, through feed materials to ore, security generally may be said to require less effort—fewer fences, fewer guards, and less money The day we lose sight of this is the day we will weigh ourselves down with the armor of security to the point where it will seriously ham per our work Security, therefore, is not an abstract problem, but a very real, a very practical, a very specific, and a very fluid problem

I recall one instance some time ago when a gentleman who was a member of Congress became concerned about the effort the Commission was making to keep track of fissionable materials He thought it might be improved As I remember, his conversation with one of the members of the Commission staff went something like this

"Do you really know exactly how much fissionable ma terial you have in process in that plant?"

'We have a good idea, since we know how much we put in"

"But do you know how much is actually in process in the plant?"

"No It doesn't come out until many months later We'd have to shut the plant down to find out, and that would take time, and production would be lost'

"Well, suppose you shut the plant down once every month and took inventory, just exactly how many days of production would you lose each month?"

"About forty-five'

I tell this story only to give an extreme example of a place where a line had to be drawn because the cost of security far exceeded the value Actually, the real cost of security is almost impossible to measure One can add up the number of guards, the cost of the fences, the cost of safes, the number of people who keep tabs on fissionable material and documents, but this is only part of the cost—the cost that can be seen Here are some examples of this kind of cost

Of the 7,300 people employed directly by the Atomic Energy Commission at the end of 1952, 1,700 of them were engaged in security work—as guards, supervisors, investigators, or evaluators

Among the Commission's contractors, about 6,000 people were engaged in security work of one kind or another

Nearly 200 people were engaged, either part or full-time, in the review of documents to determine what needed to be held secret and what did not

About 300 people were involved directly and on a full-time basis in keeping tabs on the whereabouts of the Commission's more than a million classified documents

Over 400 people were engaged in keeping the most precise kind of records on the fissionable materials—uranium-235 and plutonium—in the possession of the Commission and its contractors The cost of this "fissionable material accountability" runs in excess of $2,000,000 per year

At just one location—Oak Ridge—there exists more than $100,000 worth of fencing But such items are only the tangible ones, the costs of security that can be seen and identified There is no way to calculate such other costs as the time devoted by nearly every Commission secretary to the task of checking secret documents in and out, the time consumed by *workmen in keeping records of fissionable* material passing through their hands, and the time and money lost by a scientist who needs some materials or information for a project that he can tell no one about.

If we could be certain that the intentions of other world powers were now, and would forever remain, peaceful, our current strenuous effort to protect sensitive information would represent a waste of energy, time, and money Secrecy would be unthinkable But we have no such assurance, and, in the present state of the world, an atomic energy program without strong security around its vitally sensitive areas would be nothing short of foolhardy

CHAPTER *xiii*

The International Atom

THE ATOM knows no nationality, race, or ideology. It will go about its sometimes productive, sometimes destructive work just as loyally for a Russian, a Pole, or a Chinese as it will for an American, a Briton, or a Frenchman. And it will turn against any of these with equal ferocity if it is mishandled or deliberately used as a weapon.

The atom obeys only one set of laws—the laws of physics. And man's mastery over the atom is directly proportional to his comprehension of these laws, which are not yet fully understood anywhere in the world. The real "top secrets" in atomic energy are those that are still held by nature. Every now and then the scientists of one nation or another wrest a new secret from nature, either by accident or by dint of great effort. When this occurs, the nation that discovers the new information may lock it in a safe and disclose it only to those it considers to be loyal and trustworthy. But nature herself remains a "security risk" that cannot be controlled. The secret that has been learned by one may be learned by another. It takes brains, knowledge, experience, skill, and resources, but these are not the exclusive possession of any one nation or any one group of nations.

I sometimes think that we in America are a little in-

clined to believe that each atom bears the inscription, "Made in U S A," except those that have been stolen from us, and that in these cases the "U S A" has been scratched out and the letters "U S S R' etched in If it is fair to say that a myth has grown up in this country in the field of atomic energy, I think the myth would go something like this

"Atomic energy was discovered and first developed in the United States in secret during World War II Although we are still ahead in the field, the Russians, with the help of traitors, successfully stole enough of our key secrets during the war to develop a program of their own and are now hot on our heels Our allies, the British, because some of their scientists came over to help us with our wartime program, also know something of these matters, but are actually running a very poor third"

At the very best, this is a glib oversimplification of the history of atomic energy development The American atomic energy program is the product of international science and the free interchange of scientific ideas and information—a free interchange that ceased in 1940, for very good reasons, and has never been fully resumed

Under no circumstances can it be said that the atom is a native-born American The most that can be said is that it is an immigrant of mainly European lineage that has taken out its first papers over here If it were possible to set a precise date when the atom immigrated to this country, I would say it was January 16, 1939, when Niels Bohr, the eminent Danish physicist, arrived in New York with the news that two scientists in the Kaiser Wilhelm Institute in Berlin, Hahn and Strassmann, had split the uranium atom

Until then the atom had been mainly in the competent care of such distinguished Europeans as

Becquerel, of France, who discovered radioactivity in 1896

Pierre and Marie Curie, of France, who discovered the radioactive element, radium, in 1898

Rutherford, of England, who developed the theory of the nature of radioactivity in 1902, discovered the atomic nucleus in 1911, and disintegrated the first atom by artificial means in 1919

Einstein, of Germany, who developed the theory of the equivalence of mass and energy (meaning that matter can be transformed into energy as in an atomic bomb) in 1905

Bohr, of Denmark, who developed the theory of the nature of atoms in 1913

Cockcroft and Walton, of England, who in 1932 experimentally proved Einstein's theory of the equivalence of mass and energy

Chadwick, of England, who discovered the neutron in 1932

Joliot and Irène Curie, of France, who first produced radioisotopes artificially in 1933

Fermi, of Italy, who first used neutrons to bombard atomic nuclei in 1934

All of this was necessary preliminary work to the discovery by Hahn and Strassmann in Berlin, in late 1938, that it was possible to break up the uranium atom by bombarding it with neutrons In early January 1939 the two scientists announced their highly significant discovery to the world in the German scientific publication, *Naturwissenschaften* Thus Adolf Hitler, for a brief moment, had within his exclusive grasp the means for world conquest he so dearly sought But it got away from him—and it got away at least partly because his irrational racial and political policies had driven from Germany the brains that might have recognized the full potentialities of the new discovery, convinced the government of its possibilities, and won for the Third Reich the world race for the atomic bomb

Ironically, two of the scientists who most clearly recognized the significance of Hahn and Strassmann's discovery were the Germans Lise Meitner and Otto Frisch, both of whom were working in the laboratory of the eminent Niels Bohr in Copenhagen as refugees from Nazi tyranny It was they who first guessed that the splitting of the uranium atom released tremendous amounts of energy, and who also first proposed the name "nuclear fission" for the process involved Thus Bohr, who was about to embark upon a trip to the United States to compare scientific notes with his old friend Albert Einstein (also a refugee from Hitler s idea of Utopia), was provided with some real news to bring with him on his trip to the New World

The news Bohr brought to the United States fell on interested and knowledgeable ears Among those who listened with avid interest was the great Italian physicist Enrico Fermi, who by now was at Columbia University, having been made unwelcome in his homeland by the shortsighted policies of Hitler's Fascist friend and would-be partner in world conquest, Benito Mussolini Fermi was among the very first to recognize the possibility of a nuclear chain reaction in uranium—the reaction which has subsequently made possible the atomic bomb, atomic power, and the large-scale production of radioisotopes And it was Fermi who, three years later, built the world's first nuclear chain-reacting pile in the squash court beneath the west stands of Chicago's Stagg Field, and thus opened the portal into the atomic age

As soon as the news of fission reached the United States, Hahn and Strassmann's experiment was repeated and confirmed at Columbia University, Johns Hopkins University, the Carnegie Institution of Washington, and the University of California And, with Fermi and another European refugee, Leo Szilard of Hungary, taking the lead, it was only a matter of weeks before conclusive evi-

dence of the following basic and highly significant facts had been developed

1 That uranium atoms could be made to split in two

2 That great quantities of energy were released in the process

3 That neutrons were produced in the fission process that in turn could split other uranium atoms and thus set up a nuclear chain reaction

Bohr, who remained in the United States from January until May of 1939, aided in the rapid accumulation of knowledge during this period by developing with John Wheeler of Princeton a theory that subsequently led to the demonstration of the special susceptibility of uranium-235 and plutonium to fission

But world leadership in the atomic energy field had not yet shifted to the New World News of Hahn and Strassmann's experiment had also spread across Europe, particularly to the laboratory of Frédéric Joliot in Paris, who, together with his colleagues Kowarski and Halban, was independently and almost simultaneously duplicating much of the work being done in the United States, and reaching the same conclusions Frisch in Copenhagen also independently confirmed the results obtained by Hahn and Strassmann in Berlin And it is significant that, during this same period of intense activity in the laboratories of Europe and America, two Soviet scientists, Flerov and Petrazhak, announced their discovery of the phenomenon of spontaneous uranium fission in the U S S R

The results of all of this work were freely published Thus it was that by mid-1939 all the world had the essential fundamental information upon which to base an atomic energy developmental program for war or peace

How, then, was it that the United States, uniquely among all the nations of the world, got into the bomb business during World War II? Perhaps the best answer to this question is contained in the following letter, written Au-

gust 2, 1939, from Professor Albert Einstein to President Roosevelt

Albert Einstein
Old Grove Road
Nassau Point
Peconic, Long Island
August 2nd, 1939

F D Roosevelt
President of the United States
White House
Washington, D C

Sir

Some recent work by E Fermi and L Szilard, which has been communicated to me in manuscript, leads me to expect that the element of uranium may be turned into a new and important source of energy in the immediate future Certain aspects of the situation which has arisen seem to call for watchfulness and, if necessary, quick action on the part of the Administration I believe therefore that it is my duty to bring to your attention the following facts and recommendations

In the course of the last four months it has been made probable through the work of Joliot in France as well as Fermi and Szilard in America—that it may become possible to set up a nuclear chain reaction in a large mass of uranium, by which vast amounts of power and large quantities of new radium-like elements would be generated Now it appears almost certain that this could be achieved in the immediate future

This new phenomenon would also lead to the construction of bombs, and it is conceivable—though much less certain—that extremely powerful bombs of

a new type may thus be constructed A single bomb of this type, carried by boat and exploded in a port, might very well destroy the whole port together with some of the surrounding territory However, such bombs might very well prove to be too heavy for transportation by air

The United States has only very poor ores of uranium in moderate quantities There is some good ore in Canada and the former Czechoslovakia, while the most important source of uranium is Belgian Congo

In view of this situation you may think it desirable to have some permanent contact maintained between the Administration and the group of physicists working on chain reaction in America One possible way of achieving this might be for you to entrust with this task a person who has your confidence and who could perhaps serve in an inofficial capacity His task might comprise the following

a) to approach Government Departments, keep them informed of the further development, and put forward recommendations for Government action, giving particular attention to the problem of securing a supply of uranium ore for the United States,

b) to speed up the experimental work, which is at present being carried on within the limits of the budgets of University laboratories, by providing funds, if such funds be required, through his contacts with private persons who are willing to make contributions for this cause, and perhaps also by obtaining the cooperation of industrial laboratories which have the necessary equipment

I understand that Germany has actually stopped the sale of uranium from the Czechoslovakian mines which she has taken over That she should have taken such early action might perhaps be understood on the ground that the son of the German Under-Secretary

of State, von Weizsacker, is attached to the Kaiser-Wilhelm-Institut in Berlin where some of the American work on uranium is now being repeated

Yours very truly

/signed/ A EINSTEIN

(*Albert Einstein*)

It is worth noting, I believe, that this letter was instigated by a small group of foreign-born U S physicists centering on Leo Szilard, Eugene Wigner, Edward Teller, V F Weisskopf, and Enrico Fermi, and that it was delivered to President Roosevelt by the Russian-born New York economist Alexander Sachs These same scientists also pressed among their colleagues for the voluntary restriction of publication of articles in the field of nuclear fission, an objective which was accomplished, after some reticence on the part of Joliot of France, in April 1940

As a result of Sachs's visit to Roosevelt with the letter from Einstein, an official three-man 'Advisory Committee on Uranium' was appointed The functions of this group, enlarged and strengthened, were later taken over by the National Defense Research Council, the Office of Scientific Research and Development, and ultimately, in May 1943, by the Manhattan Engineer District of the U S Army Thus the American atomic energy program was launched on a voyage that has taken it to Chicago and the first nuclear chain-reacting pile, to Alamagordo and the first atomic bomb, to Idaho and the first experimental production of nuclear power, and to plants and laboratories all over the country where weapons are developed and tested, where radioisotopes are in use, and where power plants for submarines, aircraft, and commercial power production are being developed—to a considerable extent behind a tight wall of official secrecy And, encouragingly, it has been a voyage captained in large part by such leading American scientists as Walter Zinn and Alvin Weinberg

(reactor development), J Robert Oppenheimer and Norris Bradbury (weapons research), Glenn Seaborg (transuranic elements), Frank Spedding (metallurgy), and Ernest O Lawrence (high energy particles) Zinn and Spedding, interestingly, were born in Canada

In Western Europe, as the lights went out in Denmark, in Norway, in the Low Countries, and in France, atomic energy research work ground to a halt almost everywhere but in Britain and Germany In Britain it continued until 1943, when the government voluntarily closed down its atomic energy program and transferred its key scientists to Oak Ridge, Los Alamos, and Berkeley in the United States to assist in the rapid development of the atomic bomb far from the sting of the Luftwaffe Shortly after the Hiroshima explosion, the British government, in a statement on atomic energy, said

"The effect of these transfers was to close down entirely all work in the United Kingdom on the electromagnetic process and to reduce to nothing the nuclear physical research Nevertheless, there is no doubt that this was the proper course to follow in the light of the decision which had been taken to give the highest priority to the production, in the shortest time, of an atomic bomb for use in this war"

While this all-out, integrated program was being carried on by the United States and Great Britain, joined by Canada, the Germans were acquiring considerable quantities of heavy water from captured Norway and were apparently using it in a nuclear research program of their own Actually, we found out later that they were far behind the point we believed they had reached But they still had a good deal of scientific talent, and they had a definite interest in heavy water Except for the cold water that Hitler poured on their heavy-water program, Germany might have caught up with us before the end of the war But Germany didn t, and the end of the war brought an

end to her atomic energy program, such as it was, as well.

The conclusion of World War II, then, partly because of our prodigious investment of time and money and skills, partly because of the assistance of Britain and Canada, and partly because of the engineering and scientific genius of our own people, found the United States well ahead of the rest of the world in atomic development. The end of the war also witnessed the departure of the scientific missions from England and Canada to their own countries to develop their own programs. With the exception of some exchanges of information not having to do with weapons or power plant development, they have worked since the war separately and apart.

But we should never get the idea that World War II placed atomic energy development in a state of permanently suspended animation throughout the world, with the United States well in the lead and everyone else perpetually behind. Monopoly of scientific discovery and progress is a virtual impossibility, and there are many countries besides the United States that possess the four basic ingredients of a successful atomic energy program: raw materials, scientific ability, industrial resources, and the will to progress.

It is not generally realized in the United States that most of the major countries of the Western World have launched national atomic energy programs since the war's end in 1945, some drawing on the fruits of their own scientific past, and all drawing on the extensive non-secret knowledge that has been placed in the public domain from the wartime program of the United States, Great Britain, and Canada. And those few nations that have no program for atomic energy production and development almost invariably exercise close control over raw materials in the expectation that they will be needed at some future date.

Only three countries now have atomic weapons programs, or are now capable of manufacturing the necessary ingredients of atomic bombs in quantity These are the United States, Great Britain, and Russia Two additional countries, Canada and France, will, within the next few years, have nuclear reactors that can produce rather significant amounts of plutonium, from which atomic weapons can be made This does not mean that no other country now has or will ever have reactors, the basic tool of an atomic energy program Research reactors are already in existence in France, Canada, and Norway (which has a joint program with the Netherlands), and others are under construction in Belgium and Sweden It is safe to predict, I think, that the next five years will see research reactors built and in operation in at least a dozen countries of the world

Although the United States and Great Britain keep their work on weapons, fissionable materials, and power reactors almost entirely secret, most of the world's free nations, including Britain and the U S, have helped one another to obtain the necessary knowledge, materials, and equipment for basic atomic energy research progress, and for the development of peaceful applications in such fields as medicine and agriculture An example of the kind of co-operation between nations that is beginning to speed the resurgence of European science is the new ten-nation scientific organization known as the European Council for Nuclear Research, which is undertaking to build a Central European Research Laboratory in Switzerland, on the French-Swiss border near Geneva The Council was formed last year under the auspices of UNESCO, and its work is being carried on with some technical assistance from Great Britain and the United States

The member nations of the Council are Belgium, Denmark, France, Italy, the Netherlands, Norway, Sweden, Switzerland, West Germany, and Yugoslavia Great Brit-

ain plans to join in the near future The Council's activities are being entirely supported by the member nations, and are being carried on under four working groups headed by Niels Bohr of Denmark, Odd Dahl of Norway, C J Bakker of Holland, and Leo Kowarski of France As two of its first orders of business, the Council plans to erect at the Central European Research Laboratory a 30-billion-electron-volt cosmotron and a 600-million-volt synchrocyclotron to probe the mysteries of atomic nuclei I think it is pertinent to mention that the lessons learned in the construction of the cosmotron at our own Brookhaven National Laboratory (which is but a 3-billion-volt machine) are being made available to the Europeans At present the Council has no plans for a reactor, but many of its member nations either now have or plan to build reactors of their own in the near future The idea of the Central Research Laboratory is not to drain off, but rather to build up, the quality of research in each individual member nation

There are many reasons why a nation may wish to undertake an atomic energy program even though it has no intention of ever making an atomic bomb One of these is national pride Another is the desire to produce atomic power to supplement or supplant the other, more orthodox sources of power, and possibly to propel ships Still another is the need for radioisotopes for medical and industrial applications But in every case there is also a desire to provide research facilities to hold and stimulate the interest of young scientists Most of the smaller countries of the world have been concerned with the problem of keeping their bright young men at home With relatively limited opportunities for research work, and consequent advancement and recognition, the young scientists of the smaller countries have had a strong incentive to leave for the larger research centers outside their own borders And, particularly in those countries which suffered war's de-

struction, frustration, and hardship, there has been a notable tendency for the younger men to leave for the New World

In the years which lie ahead, the United States must face up to and resolve the problem of what its long term relationship to these fast-growing foreign programs will be Should we encourage and assist them, or should we remain aloof and alone? And if we do assist them, should we do so to the extent of encouraging them to spend the vast sums that are necessary for the facilities in which weapons and weapons materials are made?

Before attempting to answer these and related questions, it would be helpful, I think, to examine rather closely what is being done in each country, together with some of the historical background that helps to explain why it has reached the position it occupies today

UNITED KINGDOM

Britain is the land of Rutherford, Soddy, Cockcroft, Walton, and Chadwick—all great names in the history of nuclear research Moreover, the English institutions of higher learning, such as Oxford, Cambridge, Birmingham, Liverpool, Bristol, and King's College, have been centers of research and training in science and technology for generations The consistently fine quality of British science is amply attested by the fact that more Britons have won Nobel prizes in physics than the scientists of any other nation, and the "tight little isle" has stood very near the top in chemical and medical awards as well

Britain temporarily suspended her own atomic energy development in 1943, when she sent most of her top atomic scientists to North America to work jointly with the United States and Canada in the development of the atomic bomb But when these people left Britain they left behind them a good share of the world's supply of nuclear research equipment—equipment that has been added to in

considerable quantity since the war. Today many British institutions possess such instruments as cyclotrons, synchrotrons, electrostatic generators, and other high-energy atom-smashers for training purposes and for basic nuclear research.

It was not until October 1945, when World War II had been won and Britain's scientists began to return home, that the British government decided to set up a research and experimental center in the field of atomic energy. The site chosen was the RAF airdrome at Harwell in Berkshire, which was convenient to both the educational center at Oxford and London. By the end of one year the staff had grown rapidly and included engineers of all kinds, metallurgists, chemists, and a great variety of experts in almost every branch of pure and applied science. The staff members, headed by the distinguished scientist Sir John Cockcroft (appointed in January 1946), were drawn from the British teams returning from the United States and Canada, and from British universities, industrial concerns, and government laboratories.

It didn't take the British very long to provide themselves with the primary tool of present-day nuclear research—a nuclear reactor. The first reactor in Britain, called GLEEP (for Graphite Low Energy Experimental Pile), was completed at Harwell in August 1947. It is a purely research reactor, and is still being operated twenty-four hours a day for this purpose. A second reactor, called BEPO (for British Experimental Pile O), was completed in July 1948. BEPO is a higher-powered reactor than GLEEP, and it is used for the production of radioisotopes as well as for experimental purposes. In addition, since 1951 the heat produced by BEPO has been used to warm several of the buildings at Harwell at an annual saving of about two thousand tons of coal.

In the scope of its work, the Atomic Energy Research Establishment at Harwell resembles the American lab-

oratories of Oak Ridge in Tennessee, Argonne in Illinois, and Brookhaven on Long Island In addition to its reactors, it also has "hot" laboratories for work with highly radioactive materials, instrument development shops, medical and metallurgical research laboratories, such high-energy particle accelerators as cyclotrons and synchrocyclotrons, and a radioisotope packaging and distribution center Harwell's isotopes, produced in BEPO, go to research projects, hospitals, and industrial concerns in the United Kingdom, the British Commonwealth, Europe, and Asia Last year over nine thousand shipments were made, approximately one third of which went to thirty-seven countries outside the United Kingdom Assisting Harwell in the isotope program is a Radio-Chemical Center at Amersham in Buckinghamshire

In the United Kingdom there is a growing interest in atomic power, stemming in part from Britain's serious fuel problem Accordingly, a group at Harwell has been occupied since the beginning with the problems of producing heat and power from atomic energy Two years ago ten per cent of the effort at Harwell was devoted to this project, but recently the ratio has been stepped up substantially As a result, a low-power breeder reactor is now under construction, and design work is going forward on a high-power breeder, a natural-uranium power reactor, and an enriched-uranium prototype of a reactor for ship propulsion Recently Sir John Cockcroft said there is "cautious optimism about the long-term future in this field"

Harwell, diversified as it is, is not the only atomic energy establishment in Great Britain The United Kingdom also has a program to make fissionable materials for weapons and for reactors The headquarters for the fissionable materials production program is at Risley in Lancashire, the plutonium production center is at Sellafield in Cumberland, the uranium-235 production center is at Capen-

hurst in Cheshire, and the uranium ore processing center is at Springfields in Lancashire Harwell, in addition to its research work, provides technological assistance to the production programs, including help in the design of the large plutonium-producing reactors at Sellafield Britain also has a weapons program under the very capable direction of Dr W G Penny, and tested its first atomic bomb last October in the Monte Bello Islands off the coast of Australia

The British atomic energy project is therefore a comprehensive and completely integrated one The British have access to the uranium ore they need, they produce the fissionable materials uranium-235 and plutonium, and they can, and do, make atomic weapons Their basic and applied research is extensive, and they are exploring diligently the peaceful applications of the atom

As in the United States, the entire British atomic energy program is under government ownership and control This was provided for in the British atomic energy act of 1946, which placed the entire program under the Minister of Supply, a member of the Cabinet He has the power to make grants of public funds for research and production, to build and operate plants and laboratories, and to authorize searches for uranium He may seize minerals and deposits, and he may prohibit the treatment, processing, or transfer of fissionable materials

There are many in Britain today who feel that the British program would be much more effective if it were to be established under an independent agency, such as a government corporation, or a commission, as in the United States, rather than as a part of one of the established older departments of government It is not unlikely, therefore, that in the near future the organizational structure of the British program may be radically changed But no matter how it is administered, it is quite safe to predict that its output will be impressive and of very high

quality This fact raises the question of what our relations should be with the United Kingdom in the exchange of information in the field of atomic energy

The partnership of wartime days between the United States and the United Kingdom in the atomic energy field was ended by the prohibitions in the American Atomic Energy Act of 1946, which forbade interchanges of information with foreign countries relating to the production of fissionable materials and the making of atomic weapons In fact, by one interpretation at least, there can be no exchange of information in the field of atomic power development and production

There are certain non-sensitive and rather narrow fields, such as health and safety, isotope techniques, and low-power research reactors, where exchanges of information between the two countries and Canada still take place There is also a close relationship, and there always has been, in the field of uranium ore procurement Most of the agreements that were entered into several years ago with the countries that produce ore for the Western World were worked out jointly by the United States and the United Kingdom In addition, there is an agreement between the United States, the United Kingdom, and Canada that no sensitive information jointly shared by the three countries during the war may be declassified or passed on to any other foreign country without the consent of all parties to the agreement This means that there must be joint conferences from time to time to determine precisely what should be held and what should be released in the way of information But in every other sense, the wartime co-operation between Britain and the United States has ended

Few people who have thought about the problem at all believe that it makes very much sense for these two great and traditionally friendly countries to go their separate ways in the new and challenging field of atomic

energy At the same time, however, many of these people feel that until British security methods are tightened, at least to the point where a Bruno Pontecorvo cannot merrily wing his way from Harwell to Russia without some kind of restriction, we cannot afford to be full partners

In the event of a wholesale aggression against the West by the U S S R , American atomic bombs undoubtedly would be committed to the defense of Britain It does seem a bit ludicrous, therefore, that the first British bomb should have been detonated without American scientists having had at least a peek at it If there are novel and useful things about that first British weapon (and the British designers are of the very best), why should they not be incorporated into the bombs that may someday be used to protect England from aggression? And if we can learn something from the British engineers and scientists who are attempting to extract useful power from the atom—as it seems clear we could—shouldn't we be learning?

The goal over the next few years, it would seem to me, should be this a wide base of co-operation between the scientists and engineers of the United States and Great Britain in the new and challenging field of atomic energy, a co operation, however, that would be conducted in such a way that the Soviet program would not be advanced

Canada

Canada, unlike the United Kingdom, is not interested in making atomic bombs She could make them, but she has wisely decided not to expend her energy in this frightfully costly pursuit She is understandably interested, however, in exploiting in every possible way her abundant uranium resources so that they may contribute to the defense of the Western World and ultimately provide Canada with whatever blessings a split atom may bestow

Canada first became officially interested in atomic energy in 1940, when the National Research Council began to sponsor nuclear experiments Late in 1942 Great Britain joined Canada in the establishment of a laboratory at the University of Montreal Canada provided part of the staff, and Britain sent over a research team, including some French refugee scientists, that had been working at Cambridge University The Montreal project—later joined by an American team—was interested principally in slow-neutron research, and it maintained close contact with the Americans under Fermi in Chicago who were developing the first chain-reacting pile

It was early in 1944 that Canada decided to build its first experimental nuclear reactor The site chosen was Chalk River, 125 miles west of Ottawa The reactor, utilizing uranium and heavy water, was completed in the fall of 1945—the first reactor to go into operation outside the United States Called ZEEP (for Zero Energy Experimental Pile), it has no cooling system and can put out but a few watts of energy The reactor is still in operation, however, and is used primarily as a research instrument in nuclear physics and for testing reactor materials

In 1947 the Canadians completed a much larger and more powerful reactor, known as NRX (for National Research Experimental), which is also located at Chalk River and which also uses uranium metal with heavy water as the moderator While NRX is designed in such a way that it can produce only small quantities of plutonium, it for a long time had a greater concentration of neutrons than any other research reactor in the world This made it uniquely valuable for many types of research and for the production of highly irradiated isotopes The designed heat output of the NRX reactor is 10,000 kilowatts, but it has normally been operated at higher levels Late in 1952 an accident occurred in NRX that has temporarily put it out of commission It is now being re-

paired with the assistance of American technicians provided by the Atomic Energy Commission and the Navy

Still a third Canadian reactor, also to be moderated with heavy water, is now under construction at Chalk River It will cost in the neighborhood of $30,000,000, in contrast to the $5,000,000 invested in the NRX pile The new reactor will be capable of producing rather sizable quantities of plutonium, and it should also be of great value to the Canadians in investigating the problems of economical power production and of breeding Canada also has plans to start construction on a real power-producing reactor as soon as the third reactor, called NRU, is completed

In addition to being the site of all Canadian reactor construction to date, Chalk River, in the nine years it has been in existence, has grown into a well-rounded, well-equipped modern atomic energy laboratory This atomic energy research center of Canada occupies some hundred buildings on a closely guarded eighty acres along the Ottawa River The central area is surrounded by a larger, controlled reservation of some 10,000 acres Twelve miles away, at Deep River, the project maintains an attractive community to house the 1,300 or so workers, of whom about a third are scientists and engineers

Chalk River is the principal source of the isotopes used in Canadian universities, research laboratories, hospitals, and industries Several hundred shipments are made each year, some of them to other countries, including the United States One of the most valuable products of the Canadian radioisotope program is very highly irradiated cobalt for use in cancer research Chalk River is also well equipped with such machines as X ray and Van de Graaff generators, electroscopes and other specialized research devices

Chalk River tries to encourage as much university participation as possible Consequently, we find a growing

interest among Canadian institutions of higher learning in the field of atomic energy For example, at the University of Saskatchewan there is a 25-million-volt betatron At McGill University in Montreal there is a brand new radiation laboratory where Canada's only cyclotron is located The University of British Columbia has a 4-million-volt Van de Graaff generator, Queen's University in Kingston, Ontario, has a 70-million-volt synchrotron, McMaster University at Hamilton, Ontario, performs important work in mass spectrometry, and the University of Montreal is a leader in cosmic-ray and isotope research

Like the atomic energy programs of the United States and Britain, the Canadian program operates under an atomic energy law passed in 1946 The law set up an Atomic Energy Control Board, which has power to regulate all atomic energy materials and products The board, currently headed by Dr C J Mackenzie, reports to a committee of the Canadian cabinet chaired by the Rt Hon C D Howe, minister of defense production and of trade and commerce The Chalk River Establishment is operated by a Crown company called Atomic Energy of Canada, Ltd, also headed by C J Mackenzie, and including directors from both government and industry

Canada's other important atomic energy activity—the mining and processing of uranium ores—is controlled by another Crown company, Eldorado Mining and Refining, Ltd This company, headed by W J Bennett, is the only authorized buyer of radioactive minerals in Canada As we have seen in the chapter on uranium ore, quantities of pitchblende have been produced at Port Radium on the Great Bear Lake and refined at Port Hope, Ontario, since the middle of World War II Numerous other uranium deposits have been located more recently at various points across the continent, and several of them, including some very promising ones in northern Saskatchewan, are under active development

All in all, Canada is one of the countries of the world that is in the forefront of atomic energy development today Her scientific community and her principal research center at Chalk River are of the highest caliber, and her uranium deposits are among the world's best Canada contributed substantially in talent to the wartime partnership with the United States and Britain, and her relationships with the United States, despite the restrictions in our own law, have been of the finest Canada is a real friend in this atomic energy business, and I would very much like to see the day arrive when she is made more of a partner

FRANCE

The historical role that France has played in science in general, and in nuclear physics in particular, has been an outstanding one, marked by splendid and original contributions over a period of many decades The roster of the great French men and women of science includes, for example, such names as Lavoisier, Descartes, Ampère, Laplace, Fourier, La Grange, Carnot, Pasteur, Becquerel, the Curies, de Broglie, and Joliot Their discoveries range from oxygen to radioactivity, and there is abundant reason for national pride in the history of French science

Although France cannot claim the discovery of nuclear fission itself, Frédéric Joliot and his co-workers in Paris, immediately following its discovery, showed that the neutron-induced fission process releases more neutrons than are absorbed From this they inferred (about the same time as Fermi and his colleagues in the United States were reaching the same conclusion) that a nuclear chain reaction yielding great quantities of energy was possible Joliot and his associates actually took out patents in Switzerland, Sweden, and Ecuador on a proposed uranium chain-reacting pile a year or two before Fermi and his Chicago staff showed experimentally that one could be made to work

France, then, has had something of a proprietary feeling about uranium fission French ambitions, however, suffered mortal blows from two sources First was the invasion of France, which suspended all important research in nuclear physics in that country Second was the successful development of the atomic bomb in the United States, which obviously and dramatically put America in the forefront in the field of atomic energy But an intense and justified national pride motivated France to attempt, at the end of the war, to regain her former position

At the time of the German invasion, five of the leading physicists of France escaped to England and later to North America They played an active part in research on reactor development during the war, although by agreement they remained in Canada Three of the five, including Leo Kowarski, now chief of reactor development of the French project, have since returned home to bolster the atomic energy program of France Kowarski played a leading part in the design and construction of Canada's first reactor, ZEEP

The development and application of atomic energy in France is, by government decree, entirely under the control of the Commissariat à l Energie Atomique (CEA), an organization set up by the government in 1945 with the advice and under the direction of Frédéric Joliot, clearly one of the world's foremost nuclear physicists and an avowed Communist The Commissariat is responsible directly to the prime minister, who has the power to appoint and remove members This power was exercised two years ago when Joliot was removed from the post of high commissioner of the CEA While there are in the French project some rabid anti-Communists, there are still enough Communists remaining to make it only prudent to assume that anything of significance developed on the French project is relayed eastward with little delay

The French program, unlike those of the United States, Great Britain, and Canada, has from the very beginning been operated completely in the open Secrecy is virtually unknown

The principal installations of the French project are at three locations in the general vicinity of Paris One is Fort de Chatillon, a short distance southwest of Paris Here is located the first nuclear reactor to be built in Western Europe, excluding the British Isles The reactor, called ZOE, has been in operation since December 1948 It is a low-power research reactor using uranium oxide as fuel and heavy water as the moderator

The second site of French atomic energy activity is Christ de Saclay, seventeen kilometers beyond Chatillon Saclay is the home of France's second reactor, which began operating last October Known as P-2, it also uses heavy water as a moderator Of substantially higher power than ZOE, P-2 can produce significant quantities of plutonium if desired, but the French have announced their intention of using it primarily for isotope production and research purposes The Saclay laboratory is also a general atomic research center, with equipment including a 25-million-electron-volt accelerator

France's third atomic energy installation is at Le Bouchet, thirty-five kilometers due south of Paris Le Bouchet is devoted to uranium chemistry and the preparation of fuel slugs from French uranium deposits for ZOE and P-2

The French atomic energy program is currently headed by Francis Perrin, a scientist of world-wide reputation who taught physics at Columbia University in 1940 as a visiting professor The program has over a thousand employees, of whom about a fourth are well-qualified engineers and scientists

France also has several high-energy accelerators at such locations as the College de France in Paris and the University of Strasbourg, and is installing several more

She has maintained friendly relations with the scientists of the other countries of Western Europe and is indebted to Norway for the heavy water used in her first reactor In the Saclay and Chatillon piles she produces radioisotopes in substantial quantities for shipment to hospitals and industrial concerns in France and to neighboring countries She is also an active member of the ten-country European Research Center established recently just over the French border in Switzerland

France, therefore, has the talent and the equipment for a fully integrated and well-rounded atomic energy project Moreover, she has sufficient uranium ore available within her own borders to support an active research and development program, as well as possibly sizable additional reserves in her African colonies The French know how to process uranium ore and to make it into reactor fuel. And they know how to build reactors that can produce substantial quantities of plutonium that, if the French wished, could be made into atomic weapons

France at the moment, however, has no weapons program and apparently does not intend in the immediate future to engage in one Just recently she announced a fifteen-year effort directed toward the development and construction of a network of atomic power plants For the first five years the French National Assembly has provided \$108,000,000 for this program, compared with the \$48,-000,000 that was available from 1946 to 1951 France has a strong incentive to develop nuclear power because of her lack of petroleum and the inadequacy of her domestic coal deposits During the first five years of her fifteen-year power development plan, France expects to build two additional reactors primarily for the production of plutonium fuel at sites yet to be selected

During the next five years, as plutonium becomes increasingly available in France, there will doubtless be pressures from the French military establishment to get

into the weapons business But France would do well to follow the example of Canada and devote her energies to research and to the realization of the peaceful uses of atomic energy, making her military contribution to the security of the Western World in another area

NORWAY *and* THE NETHERLANDS

It is appropriate to discuss the atomic energy programs of these two countries together, for they jointly operate the only nuclear reactor in the free world outside of the United States, Great Britain, Canada, and France The reactor, located at Kjeller, near Oslo, in Norway, is a research and radioisotope-producing device designed to operate at one hundred kilowatts, although it has been operated at levels as high as three hundred kilowatts It is called JEEP, and was completed in 1951, utilizing heavy water from Norway and uranium that the foresighted Dutch had purchased in 1939 from Belgium for possible atomic energy use The uranium was hidden in the Netherlands throughout the German occupation

The Norwegian-Dutch partnership in atomic energy dates back to 1950, and the Kjeller activity, which includes "hot" laboratories and physics research facilities as well as the reactor, bears the name "Joint Establishment for Nuclear Energy Research " The Establishment is directed by a six-man Atomic Energy Board upon which Norway and the Netherlands have equal representation, and the chairmanship is rotated among all six members None of the work at Kjeller is secret, and the staff includes people from such other countries as Sweden, Switzerland, Italy, Yugoslavia, and the United States as well as Norway and Holland

Norway's current interest in atomic energy is not surprising, for the Norsk Hydro Plant at Rjukan has been producing heavy water for use in the nuclear research laboratories of the world since 1934 One of the most colorful

chapters of World War II revolves around the efforts of the Germans to obtain heavy water from this plant for their atomic energy program, and the equally determined efforts of the British Commandos and Norwegian underground to keep them from succeeding Leif Tronstad, professor of chemistry at the Norwegian Institute of Technology in Trondheim and the man who got Norsk Hydro into the heavy-water business in the first place, was killed during the war on a secret mission to Rjukan to prevent German exploitation of the heavy-water plant The plant was partly destroyed during the war, but it was running full-scale again by 1946, and it provided the heavy water for the Kjeller pile

In addition to the Kjeller laboratory, Norway also has active nuclear research programs, including the use of Van de Graaff generators and betatrons, at the universities and technical centers in Oslo, Bergen, and Trondheim Two of Norway's scientists with world-wide reputations in atomic energy are Gunnar Randers, who escaped to England and America during the war and is presently director of the Kjeller project, and Odd Dahl, who supervised construction of the Kjeller reactor Dahl is a leading figure in the new European Research Laboratory in Switzerland

Norway's principal immediate reasons for supporting an atomic energy program appear to be, first, her desire to rehabilitate her war-ravaged scientific strength and thus keep her young scientists at home, and, second, to produce radioisotopes, for which there is a large demand in Norwegian industrial, research, and medical centers For the long term Norway, even though she is one of the world's best-endowed nations from the standpoint of falling water, is nevertheless also interested in the development of atomic power With one of the world's principal merchant marines, she is particularly interested in the

possibilities of atomic power in the field of ship propulsion

The Netherlands, although a small country lacking in natural resources and large-scale heavy industrial capacity, has one distinct asset to any atomic energy program top-grade scientific and technical competence Representative of the skill and production potential of Holland is the Phillips Company of Eindhoven, a large electrical manufacturing firm with a world-wide business employing over a thousand people in its research laboratories alone Phillips built the principal nuclear research instrument in the Netherlands—a seventy-two-inch synchrocyclotron located at the Institute for Nuclear Research in Amsterdam—and also makes high-voltage equipment, Geiger counters, experimental amounts of rare metals used in atomic energy research, and a large variety of electron tubes for both export and domestic use It is capable of manufacturing almost any instrument needed in nuclear research

The principal nuclear research center in Holland is the Nuclear Research Institute in Amsterdam, headed by C J Bakker, who also heads one of the study groups of the Central European Research Laboratory in Switzerland Other institutions performing research in the atomic energy field with the aid of government funds are the Zeeman Laboratory in Amsterdam (also headed by Bakker), and the universities of Amsterdam, Groningen, Leyden, and Utrecht

The Dutch, with only limited supplies of coal and oil and no water power, are understandably interested in the possibilities of electric power from atomic energy It is no surprise, therefore, that with government participation they have recently organized a study group to look into the economic aspects of atomic energy In addition, KEMA (a research laboratory at Arnhem supported by

the Dutch power systems) has recently undertaken a joint government-industry research program on reactor development to tie in with and support the work of the Dutch team at Kjeller Holland, lacking many of the resources of larger nations, can contribute much to any joint atomic energy effort in which she might engage with other nations

Belgium

Belgium has a clear and understandable interest in atomic energy development stemming from three important and related facts (1) The rich Shinkolobwe Mine in the Belgian Congo has been the principal supplier of uranium to the Western World since the beginning of the American program in World War II, (2) Belgium, with limited fuel reserves and a steadily increasing demand for electrical energy, is in the market for atomic power, and (3) Belgium has a strong scientific and technical community

Efforts to strengthen Belgium's position in science and technology extend back at least to 1927, when the Belgian National Funds for Scientific Research were established under government sponsorship to raise and administer moneys from banks, industrial concerns, and individuals Much of the scientific equipment and other fruit of this effort, however, was lost in the war After the war the National Funds were given government grants to help reconstruct Belgium's scientific research facilities, and by *1947 sufficient progress had been made to permit the sponsorship* of research work in the new field of atomic energy From 1948 onward, the Inter-University Institute of Nuclear Physics, a subsidiary of the National Funds, has spent a substantial amount each year in support of nuclear research and training at six institutions the universities of Brussels, Liége, Louvain, and Ghent, the Royal Military School in Brussels, and the Polytechnic Faculty

in Mons, Belgium, since 1950, has had an Atomic Energy Commissioner to co-ordinate the country's atomic energy activities and advise the government on atomic energy matters.

Belgian institutions are large importers of radioisotopes, and they have performed important work in the fields of uranium metallurgy, cosmic-ray studies, and nuclear research with high-energy machines. The largest high-energy machine in Belgium, a 30-million-electron-volt cyclotron, has recently been installed at the University of Louvain. Its magnet, made in Belgium, was a gift from the mining company that owns Shinkolobwe, the Union Minère du Haut Katanga.

Belgium's plans for the future include the construction, within the next year, of a medium-power research reactor near Brussels to produce isotopes for Belgian users and to train Belgium's young scientists. The reactor will come under the jurisdiction of a newly organized Study Center for the Application of Nuclear Physics, a joint government-industry-university group headed by Pierre Ryckmans, former Congo governor, who is also Belgium's Atomic Energy Commissioner. In preparation for the construction of the new reactor, groups of Belgian scientists have, during the past year, visited for extended periods in England and at the Argonne National Laboratory in the United States to obtain non-secret information on reactor technology. Belgium is looking forward, in five or six years, to building her first reactor for the production of atomic power.

Sweden

Sweden is obviously intent upon exploiting fully her capacities in the field of atomic energy. Ever since the first atomic explosions in 1945 the Swedish government, in cooperation with her scientists and businessmen, has been active and purposeful both in fundamental scientific re-

search and in the establishment of administrative machinery for practical development

As in the case of Norway, the Netherlands, and Belgium, Sweden apparently has no intention to produce bombs, although one of her top military leaders recently said that he favors Sweden "trying in every way to get hold of tactical atomic bombs" The avowed purpose of the Swedish program, however, is to produce power for industrial and commercial use This is understandable, for Sweden's future industrial development may largely depend upon her ability to find a new source of power Of her readily available water power, some seventy to eighty per cent has already been exploited, and there is no coal worth mentioning in Sweden She does, however, have extensive oil-shale reserves that she has reserved for emergencies and has developed only on a pilot-plant scale In these shales small amounts of uranium are found, and the Swedes have perfected processes by which this uranium may be extracted

As early as 1945 Sweden appointed an Atomic Energy Commission and amended her mining laws to establish national ownership and control of uranium minerals The Commission comprises a group of thirteen scientists, industrialists, and government officials who, under the Minister of Education, act as a policy board for atomic research and allocate funds among Swedish universities and research institutions Significant scientific work is being performed at such places as the Research Institute for Experimental Physics (The Nobel Institute of Stockholm), the Royal Institute of Technology, the University of Uppsala, the Chalmers Institute of Technology, the Defense Force Research Institute, the University of Lund, the Karolinska Medical Institute, the Wenner-Gren Institute, and the Gustaf Werner Institute

Before 1946 Sweden had one cyclotron and one betatron Since then, so many other nuclear instruments and

equipment have been acquired that one might reasonably assert that Sweden has the most completely equipped nuclear science laboratories in Western Europe, next to England An example of the new equipment being added to Swedish laboratories is the new 200-million-electron-volt synchrocyclotron at the Gustaf Werner Institute in Uppsala—the second-largest such machine in Europe

Sometime within the next year Sweden will also have completed construction on her first nuclear reactor It is an experimental low-energy pile fueled with uranium metal and moderated with heavy water obtained from Norway The reactor and its associated laboratories are being built underground in a chamber blasted out of solid rock at the experiment station of the Academy of Engineering Science in Stockholm The reactor is being built by a company, AB Atomenergi, whose stock is fifty-seven-per-cent government-owned Private industries hold the remaining shares AB Atomenergi also produces and processes Swedish uranium After their research reactor is completed, the Swedes have plans to build a 10,000-to-20,000-kilowatt pilot plant for atomic power production

DENMARK

Denmark has no official or national atomic energy program, and yet it has one of the foremost centers of nuclear research in the world This center is the Institute of Physics at the University of Copenhagen The director of the Institute is the world-famed atomic scientist Niels Bohr

During the 1930's Bohr's Institute became a haven for scientists who had fled the Hitler regime in Germany Among these refugees were Otto Frisch and Lise Meitner, who, as we have seen, first interpreted to the world the results of Hahn and Strassmann s fission experiment at the Kaiser Wilhelm Institute in Berlin The German occupation of Denmark, beginning in 1940, at first did not seri-

ously interfere with the Institute's work In 1943, however, the occupation became much harsher With arrest pending, Bohr escaped in a fishing-boat to Sweden, whence he was taken to England Other scientists from the Institute found a haven in Sweden until the liberation of Denmark Bohr became a member of the British scientific mission to the United States in 1943 and, as such, took part in the wartime atomic energy program in this country

Over the years a remarkable number of the world's leading atomic scientists, including many from America, have worked in or with the Institute in Copenhagen, and many a significant international conference in nuclear physics has taken place there Temporarily halted during the war, these conferences were renewed in 1947, and the flow of scientific visitors from the United States and elsewhere continues at a high rate

The Institute of Physics has a permanent faculty and such items of equipment as cyclotrons, Van de Graaff generators, mass spectrometers, and X-ray apparatus But the significant thing about the Institute is not its equipment, nor even its well-qualified faculty, but the fact that it is dedicated, as perhaps is the research center of no other single nation, to international co-operation in the field of science

Germany

So far as the basic resources for scientific endeavor and technological progress are concerned, Germany is one of the best endowed of nations The quality of German science is proverbial Germans have won more Nobel prizes than the scientists of any other nation, being particularly strong in the field of chemistry, and the German chemical and electrical industries rank with the world s largest and best Germany has also long been a major producer of steel, nonferrous metals, and other products basic to the kind of industrial complex that could support a large-scale

atomic energy program And we should remember, too, that uranium fission was discovered in Germany

Germany in the early stages of World War II seemed to be as capable as any other country in the world insofar as developing a successful nuclear reactor and an atomic bomb was concerned In fact, it was the fear that Germany might accomplish these objectives first that had much to do with launching the all-out atomic energy effort of the Western Allies during the war The German bomb effort was later found to be somewhat meager, thanks to Hitler's emphasis on other things, but Germany did produce a quantity of relatively pure uranium—first step in the construction of a reactor

Since the war, however, German atomic energy development (in West Germany, at least) has been at a standstill by Allied decree Basic research and the utilization of isotopes in medicine, chemistry, and biology are permitted, but all work with fissionable materials is forbidden The principal basic research centers are Gottingen University, the Institutes of Atom Physics at the universities of Hamburg and Freiburg, the Max Planck Institute for Chemistry at Mainz, and the Max Planck Institute for Physics at Gottingen

If the recently negotiated contractual agreements between Germany and the Western Allies, and the European Defense Community treaty, are ratified, West Germany will be permitted to build a moderate-sized reactor for research purposes and the production of radioisotopes now imported One thing is certain the potential exists in Germany for a much stronger program than the Western Allies will be likely to permit for some time Any full-scale atomic energy effort in West Germany would also be limited by the fact that Germany's uranium deposits are in the East, where they are currently being exploited by Russia In the field of research, however, it would seem that much can be expected from Germany within the next

few years as the present bans on research reactors are relaxed and as her scientific community regains its traditional strength

ITALY

Italy has long had an internationally respected scientific community Enrico Fermi was born and educated in Italy, and taught physics in Italian institutions, where he won a Nobel Prize, before coming to the United States in the 1930's Today Italian science and technology, like those of Germany, are slowly recovering from the effects of World War II Italy suffered greatly from the war, and in some cases from the actual demolition of her university buildings She has also suffered from the exodus of leading scientists to the United States, Canada, and Latin America

Italy's foremost centers of nuclear research are the Institutes of Physics at the universities of Rome, Turin, Milan, and Padua They operate on a rather meager annual budget financed mainly with government funds The laboratories of the four Institutes are engaged almost entirely in fundamental research

In 1946 a group of Italian industrial concerns formed, with government co-operation, a privately financed company to sponsor and encourage applied research and development in the field of atomic energy The group, called CISE (Centro Informazione Studi Esperienze), is located at the Institute of Physics in Milan, and last year had a budget of $110,000 It has built small pilot plants for the production of heavy water and metallic uranium, and is currently drawing up plans for a low-power uranium and heavy-water reactor that it hopes to locate in Milan It also sponsors courses in physics at the University of Milan

Last year the Italian government established a National Committee for Nuclear Research to supervise the expenditure of official funds for atomic energy research work, including Italy's contributions to the new European

Research Center Italy has the talent and equipment to build a research reactor, and it would not be surprising if she undertook such a project within the next few years She does not appear to have the resources at present, however, for a large-scale program As to uranium, some low-grade deposits have been reported at various places in Italy, but they are not being extensively worked

SWITZERLAND

The Swiss have had a Research Commission for Atomic Energy since late 1945, and the government supports work at the Federal Institute of Technology in Zurich, where there is a thirty-eight-inch cyclotron, as well as at the universities of Zurich, Basel, Berne, Geneva, Lausanne, and Neuchâtel Switzerland regularly imports radioisotopes for use in hospitals and research laboratories, and her distinguished medical community has made useful contributions in the application of isotopes in diagnosis and therapy

Switzerland has long had a special interest in the development of atomic energy to produce useful power Her efforts along these lines, however, have been severely handicapped by her lack of uranium The Swiss nevertheless look forward to the day when they can build their first nuclear reactor

It seems quite reasonable to expect that nuclear research in Switzerland will receive a substantial shot in the arm as operation of the Central European Research Laboratory near Geneva gets under way The first equipment to be installed there will be the largest and most powerful particle accelerator in the world, and Swiss scientists, under the direction of Paul Scherrer of the Federal Institute of Technology, are expected to play an important part in the work of the laboratory

INDIA

Among the nations of Asia, India has the largest and most advanced atomic energy program It is a peaceful program, directed toward exploiting the atom as a source of power, and it is carried out under the control and supervision of the Indian Atomic Energy Commission, which was set up in 1948 when the Indian Atomic Energy Act was adopted The Indian AEC, which sponsors research projects in a number of educational and scientific institutions throughout the country, is a three-man body reporting direct to the prime minister

The leading nuclear research center in India is the Tata Institute of Fundamental Research at Bombay, which is currently looking into the possibilities of producing heavy water and of building a nuclear reactor The Institute of Nuclear Physics in Calcutta is also being built up to a leading position, and recently added a thirty-two-inch cyclotron, the only such machine in India Atomic energy research is also in progress at the Bose Research Institute in Calcutta, the University of Delhi, the Indian Institute of Science at Bangalore, the Physical Research Laboratory at Ahmedabad, and Aligarh University, among other places

India has made a good deal of progress in recent years in cosmic-ray research, and in the training of her physicists, chemists, and engineers for specialized work in atomic energy Among her accomplishments, also, is the development of a program for the use of radioisotopes in medicine, including the diagnosis and treatment of certain types of cancer and leukemia In an effort to build up her contacts with the world scientific community, India has stimulated visits by foreign scientists and encouraged their residence there for periods as long as a year or more

India has some uranium, enough, she hopes, to make her independent of outside sources of supply She has been very active in the search for atomic energy minerals, and

has a standing offer, as we do in the United States, to buy at a guaranteed price all stocks of uranium discovered She also offers rewards for the discovery of new deposits, and grants allowances for the development of mines Of possible great future significance is the fact that India has probably the world's richest deposits of monazite, a sand containing thorium Thorium, potentially, can be used like uranium as a source of atomic energy A factory to treat fifteen hundred tons of monazite sand a year is in operation in southwest India

Under the leadership of some very able scientists, India has made a determined effort to keep posted on nuclear research developments the world over, and, although she currently has only limited funds and trained personnel, she should score some real gains in the relatively near future Right now she is looking forward to the construction of her first reactor, for research and radioisotope production, within the next two years

Brazil

Brazil, in atomic energy, is to South America what India is to Asia, namely, the most aggressive country on the continent Her program of atomic energy research and development is under the control and direction of the National Research Council, which was established in 1951 The president and vice-president of the Council are officers of the armed forces, and the members include many other government officials and scientists

Brazil's nuclear research work centers around the Brazilian Center of Physical Research in Rio and the University of São Paulo, although there are a half-dozen or so additional institutions where noteworthy projects are under way, including the University of Brazil in Rio The most ambitious project yet undertaken in Brazil will be the construction of a 450-million-electron-volt synchrocyclotron at the Center of Physical Research A small cyclo-

tron for the Center is now being built at the University of Chicago, and American scientists are assisting the Brazilians in developing plans for the larger machine The University of São Paulo already has a thirty-million-volt betatron and a Van de Graaff generator

Brazil has some very competent young scientists, including C M G Lattes (presently head of Center of Physical Research), who in 1947 participated in the discovery of the subatomic particle, the meson, while studying cosmic rays A year later, while at the University of California in Berkeley, he also participated in the discovery of the artificial production of mesons in the 184 inch cyclotron there Many people consider the discovery and subsequent study of the meson to be the most important development in nuclear physics since the end of the war Brazil is also well known to the American atomic energy program as the largest importer of radioisotopes in Latin America, and as a nation which actively encourages exchange visits between her scientists and those of the United States and other countries

All of Brazil's current atomic energy effort is regarded by the National Research Council as preliminary to achievement of the main goal construction of a real nuclear reactor for research, training, and isotope-production purposes, leading to eventual utilization of the atom to produce power for commerce and industry

Among Brazil's natural resources of potential value to an atomic energy program are some sizable deposits of monazite, source of thorium These are not so large, however, as those of India While some prospecting has been undertaken for uranium at various locations over Brazil's vast land area, an intensive exploration program has never really been attempted This is unfortunate If and when Brazil locates large deposits of uranium ore, as she well may, we may expect a real intensification of her atomic energy effort Such an exploration effort, it would seem,

should have the highest priority in the program of the National Research Council

Australia

Australia has been officially interested in atomic energy since 1946, when her atomic energy law was passed It was designed primarily to make provision for the control of materials that are or may be used in producing atomic energy The administration of the law has been the responsibility of the Minister of Supply Last December an Australian Atomic Energy Commission was established under the Minister of Supply to direct Australia's atomic energy effort

The principal nuclear research center in Australia is the School of Nuclear Sciences at the National University at Canberra, which is being built up to a high level of quality with government funds The School already has a half-million-volt particle accelerator, and is now constructing a two-billion-volt synchrocyclotron Noteworthy work is also under way at the University of Melbourne, which owns a 2 8-million-volt betatron The program there includes courses in nuclear physics for officers of the armed services and government officials, and meetings of scientists from all over Australia to discuss radioisotope techniques Australia is a substantial importer of radioisotopes from America

Australia, like many other countries, is planning for the construction of her first research reactor within the next few years, work which has been given impetus by Australia's real need for a source of abundant and inexpensive power, plus the discovery, relatively recently, of promising uranium deposits at Rum Jungle in the Northern Territory and Radium Hill in South Australia Australia, recognizing her responsibilities to the security of the Western World, has recently agreed to supply uranium ore from her new deposits to the American weapons program

THE UNITED STATES AND THE FREE WORLD

While no very appreciable scientific work has been performed as yet in the Union of South Africa or Mexico, both of these countries have domestic supplies of uranium together with a growing interest in scientific research and development in the atomic energy field, and Mexico has recently established a nuclear research laboratory (South Africa, like Australia, is selling uranium to the United States and Britain, Mexico's deposits are as yet unexplored, but they are promising) In fact, it is hard to think of a nation anywhere that does not have at least the beginnings of an atomic energy program Some of the other more obvious ones that come to mind are New Zealand (with an atomic energy act passed in 1945), Cuba, Argentina (with some mavericks but also with some solid scientists), Japan (which performed some important nuclear research before the war), Ireland, and Spain

Yes, the atom is international, and it is becoming more so with each passing year America has no monopoly in atomic energy, and, indeed, has never had one The only monopoly we have ever enjoyed was the exclusive possession, for a relatively short period of time, of a supply of atomic bombs

A very large share of the American effort in atomic energy has necessarily been devoted to military work To some extent, we have consequently had to forgo certain basic and applied research projects leading to the peaceful utilization of the atom But this is not true of the rest of the free world While we have been engaged in weapons development and manufacture, our friends abroad have been busy catching up with our peaceful advancements and have been pushing on into new, unexplored areas of science While we are still engaged in our military competition with the Soviet Union, therefore, we are now also engaged in a peaceful competition with our friends and allies But our competition with the other na-

tions of the free world is a good and healthy one It is the kind of competition where one scientist says to another "Come and look at this, I think I have something that will be of use to you, I want you to know it"

In this kind of situation it would not only be ostrichlike for us to ignore the world of science around us, it might actually be dangerous To isolate ourselves from this world would be to isolate ourselves from those pioneering explorations that may someday open up new and unforeseeable applications of atomic energy

This being the case, it is our clear responsibility, it seems to me, to engage in a basic-research and peaceful-development program of our own up to the limit of our military-laden capabilities, and also to maintain the closest possible relationships with the research activities of our friends, particularly our traditional allies and the nations that have furnished the uranium that feeds our weapons program This would include assisting them wherever good scientific work was being conducted It would do us no possible good to impede these foreign efforts, and it may well do us a whole lot of good to assist them By this means we shall not only be maintaining the traditional contacts of world science, from which the world cannot help but benefit, but we shall also be helping ourselves If significant discoveries come from abroad, as they undoubtedly will, our industrial strength is such that we can quickly apply them, for our own betterment and for the betterment of our friends—and here, ultimately, is our greatest source of strength in the cold war against Communism

CHAPTER *xiv*

Behind the Iron Curtain

WERE it not for the Kremlin and the policies it has followed since the end of World War II, we would probably not have a strong atomic energy program in the United States.

Had the Soviet Union shown any real desire to achieve international control of the destructive force of the atom, had she not betrayed her ally of World War II through espionage, had she not been detected exploding atomic bombs, and had she not, when detected, falsely asserted that her atomic project was devoted entirely to the peaceful utilization of this new force, such as changing the courses of rivers and the like, the American people would probably never have supported a vigorous atomic energy program in this country. The Kremlin, therefore, deserves a "well done." But it also, unfortunately, deserves a "well done" for its own progress behind the Iron Curtain.

In assessing the Russian atomic energy program, one must consider two factors: her intentions and her capabilities. It will not be my purpose here to deal with her intentions. Information on these is available in abundance elsewhere. But whether her intentions are good, bad, or uncertain (and the evidence to date demonstrates that they are certainly not good), it would be a crime of the

first order to underestimate her capabilities It could, at the most, be but a minor misdemeanor to overestimate it

In searching for information upon which to base an objective evaluation of Russian atomic capabilities, there are three places to look official Soviet government utterances, intelligence reports, and the analyses of the experts who know Russia and the Russian people well Of these, the official utterances of the Soviet government are probably of the least value to the average American, for, whatever it is that motivates Russian officials to say something, it is very rarely a desire to tell the truth These official statements are, however, of considerable value to those who know and understand the working of the official Soviet mind, and who can place in their proper perspective the things that circumstances force the Russians to say publicly To the average person, however, these statements are little more than meaningless

Of the other two sources of information, one—intelligence data—is unfortunately not available to the general public in detailed form, because to make it generally available in this form would be to jeopardize the sources from which it was obtained Such information is, however, available to the American government, and from this information it is possible for our government to reach some generalized, but reliable, conclusions that can be passed on to the public at large In capsule form, this much can be said

1 The Soviet Union has produced fissionable material in quantity

2 With fissionable material in hand, it is not a difficult technical job to make workable atomic weapons

3 The Soviet Union has exploded three atomic bombs —one in the late summer of 1949, two in the fall of 1951

4 On the basis of the above facts and other scientific and technical evidence, there is no doubt of the existence of a supply of atomic weapons in the U S S R

This is the gist of what can be said publicly on the basis

of the intelligence information available to the United States But there is a lot more than can and should be said *about the Soviet Union and its atomic capability*—information that is based, not on secret intelligence reports, but on reliable data that can be found in the public domain if one is but willing to look for it This is the kind of information that is produced by the studies and analyses of the students of Russia and the Russian people Let us take a look at it, in the context of what is needed for a large-scale atomic energy program

In any atomic energy program of considerable size, there are four essential ingredients adequate material resources, including uranium, adequate scientific competence, adequate technological and production capacity, and the determination and ability to unite these three I shall take these up one by one, in relation to the Soviet Union

Material Resources

We have noted in Chapter II that the Soviet Union has available to her the uranium ores of the Erzgebirge region of Czechoslovakia and Saxony, one of the world's three historic relatively high-grade sources of this valuable metal, and that she is working this region energetically with slave labor The Erzgebirge region alone could support a sizable atomic energy program In addition, the geology of the U S S R is favorable, in a number of areas both east and west of the Urals, to relatively low-grade deposits of uranium ore Russia should have no more difficulty in working these than we, in the United States, have in working our own relatively low-grade deposits Taking these two facts together, there is no doubt that the Soviet Union has available sufficient uranium for a large-scale atomic energy program In addition, in the vast expanses of the Russian Soviet Empire are the fuels, the sources of electric energy, the iron, and the many other natural re-

sources that are essential to a large industrial operation such as an atomic energy program

As nearly everyone knows, the Russians in their efforts to make industrial progress have been employing a series of so-called "five-year plans" There are approximately two years remaining in the current one, and, even if they do not reach their goals, which are pretentious, they will nevertheless have the makings of an ominous war machine geared to the manufacture and use of either conventional or atomic weapons I think it is worth mentioning that we in the United States, under our democratic form of government, cannot enjoy the "luxury" of five-year plans Here we operate under a series of "one-year plans" called fiscal years At the beginning of each fiscal year our Atomic Energy Commission and our Defense Department must go to the Congress and lay out their plans for the coming twelve months and request the money needed to accomplish them Very occasionally, on specific items where long-term contracts must be entered into, they can obtain an authorization to spend money over longer periods, but over-all production plans can be made with certitude only for the duration of the fiscal year There is no doubt that this puts us at a distinct disadvantage in our competition with the vastly more integrated and long-range production programs of the totalitarian Communist states

The growth in Russian output of coal, steel, aluminum, electric power, and petroleum will be truly enormous under the current five-year plan Here are just a few examples

By 1955 the U S S R will surpass the 1952 United States coal-production figure She will increase aluminum production to 50 per cent of the 1952 figure for the United States (and as late as 1930 no aluminum was produced in the Soviet Union) Electric generating capacity will also climb to around half that of the United States And steel production will increase 62 per cent over the current five-

year plan to a tonnage figure equal to about 50 per cent of the United States output. Weak only in petroleum and rail transport, Russia is pushing vigorously ahead in both of these areas.

Although these and other figures like them show that the Soviet Union is still running somewhat behind the United States in the production of industrial materials, they also show an almost explosive rate of increase in the production of raw materials—a trend that, if continued, will bring her up to American production levels in a very short period of time. It should also be remembered, when considering these relative figures, that in Russia far less of the production of these essential materials is diverted into such things as automobiles, race tracks, hotels, and electrical appliances. It goes, instead, for increasing the productive capacity still further, and for articles of war.

Scientific Capability

Some of the best advice that has been given on what the American attitude toward Russian science should be came from Lazar Volin, of the U. S. Department of Agriculture, at a symposium held in December 1951 at a meeting of the American Association for the Advancement of Science in Philadelphia. This is what he said:

"It is a fact that many branches of science in Russia during the early years of the present century were already marching steadily ahead in full step with scientific advances elsewhere. This is fairly well known in scientific circles, where it is appreciated that a very substantial legacy of science, as of culture generally, was inherited by the Soviet regime. But it is not so well realized, I am afraid, by the layman in the West. He has been misled and confused by the Soviet propagandists and their mouthpieces, who, after long harping on the extreme cultural backwardness of Russia prior to the Revolution, have more recently made profuse claims of Russia's priority in many scientific

discoveries, on top of spectacular publicity of some spurious scientific accomplishments. This last propaganda line becomes self-defeating in its ridiculousness. But it would be most unfortunate if Soviet propaganda succeeded in bringing Russian science into disrepute and in obscuring its solid historical roots and achievements."

The historical roots of Russian science go back to the early part of the eighteenth century when Peter the Great imported Western culture into his primitive Russian Empire. In a very real sense, the first scientific laboratory in Russia was a museum in St. Petersburg called the *Kunstkamera*, where Peter collected and placed on display various chemical and physical research instruments he had obtained during his frequent trips to the scientific and cultural centers of Western Europe. It was Peter also who developed the idea for a Russian Imperial Academy of Sciences, an institution that came into being in St. Petersburg a year after his death in 1725 and has been in continuous existence ever since. Now located in Moscow, where it is used as one of the devices through which the Soviet government controls Russian science, it bears the new name, Academy of Sciences of the U.S.S.R.

From 1725 to 1917 Russian science advanced steadily, sometimes because of Czarist patronage, sometimes in spite of Czarist interference or indifference. But it advanced, and throughout the entire period it remained in close contact with the West. At first it relied almost exclusively on the West for sustenance. This came in the form of knowledge, techniques, equipment, and teachers. Many of the foremost scientists of Western Europe were drawn to Russia to spend months or years at the Imperial Academy or at the new universities that were beginning to come into being in Russia's larger cities (the University of Moscow was established in 1755). In addition, many Russian students traveled widely in the West, taking graduate degrees at Western universities or working on research

projects under the tutelage of Western scientists Later on, as Russian science began to become less of a student and more of a colleague of the West, many of Russia's leading scientists visited Western institutions as teachers and as research collaborators, to the profit of the West

During the last half of this two-century period Russia contributed many a star to the galaxy of world scientists Of all these, perhaps the name most widely known in the Western World is that of Mendelyeev As almost every high-school physics or chemistry student knows, it was Mendelyeev who in 1869 discovered the relationship between the physical properties and atomic weights of the elements of the earth The periodic table showing this relationship may now, with later modifications and improvements, be seen on the walls of classrooms and laboratories in all parts of the world Any list of important Russian scientists would also have to include the physiologist Pavlov, who won the Nobel Prize in medicine and physiology in 1902, the pathologist Metchnikov, who shared the Nobel award in medicine with Ehrlich of Germany in 1908, the mathematician Lobachevsky, who discovered non-Euclidian geometry simultaneously with Bolyai in Hungary, and such others as the chemist Butlerov, the physicist Lebedev, and the mineralogist Vernadsky, all of whom have made distinguished names for themselves in the West

Russian scientific progress was badly damaged, however, by the Bolshevik Revolution of 1917 and the civil war that followed Many of the more prominent scientists understandably left the country and became exiles, and those who remained were regarded—as former members of the intelligentsia of the Czarist regime—with a good deal of suspicion or outright hostility by their new proletarian overlords

To supplant these distrusted but nevertheless useful holdovers from Imperial Russia, the Communists attempted to train a new class of scientists and engineers

from among the workers and peasants, but this did not meet with much success Soviet science nevertheless continued to progress throughout the 1920's, although it undoubtedly did not progress as rapidly as it might have if so many leading figures in Russian science had not been driven to Western Europe and the New World (Some came to the United States, and the excellence of their work not only helped our own scientific progress, but also gave us a good insight into the really high level of quality Russian science had attained)

One reason why science in Russia continued to advance during the decade following the Revolution was that no real attempt was made by the government to control or subvert free scientific inquiry, and most of the day-to-day contacts of Soviet scientists with the scientists of the rest of the world remained intact It was scientists as members of the suspected intellectual class that the Soviets didn't like, not science *per se*, and the ideal of free science continued to persist, probably because the government had not yet had time to turn its attention to this still undisciplined inhabitant of the workers' paradise

In the 1930's, however, two things of considerable importance happened First, the Soviet government suddenly recognized the intelligentsia as "a pillar of Soviet society " The scientist, as a member of this class, no longer had to slink in the back door, he was suddenly invited into the parlor Rubles, ration cards, Stalin prizes, and commodious quarters began to come his way in abundance, and the leading scientists achieved a status in the Soviet Union equal to that of the leading bureaucrats Moreover, the children of the upper-middle-class intelligentsia began to be eligible for scholarships in the leading institutions of learning, and science in general acquired a new and valuable source from which to draw recruits

But something else began to happen The State began to take an increasing interest in just what its scientists

were doing In other words, it became interested in science as science The heavy hand of "policy" began meddling with the delicate and objective experiments taking place on the laboratory bench This had a number of interesting results One of the first was the isolation of Soviet science The Iron Curtain was lowered between the scientific communities of the East and West This happened in the 1930s when a steadily increasing number of Russian scientists who had accepted invitations to scientific meetings in the West found only the implacable smile of the Foreign Office functionary where their passports should have been They didn't leave the U S S R, and virtually no scientist, other than a few trusted spouters of the party line, has left since Nearly all invitations to Western scientific meetings are refused, if they are acknowledged at all And the same thing is true of all but a few Western scientists who have attempted to obtain Russian visas to travel in the other direction The traditional "one world" of science became two

Another result of the Soviet government's increased interest in science, perhaps designed to compensate for her lack of contact with the West, was a concerted effort to corral and hold in Russia all the scientists it could lay its hands on The no-passport policy was part of this effort, and it was useful to the Soviets, for it served to eliminate the gradual attrition caused by those who left for a scientific meeting in London, Paris, Copenhagen, or New York and decided not to go back to Russia Also, as part of this effort, the Soviets instituted a program designed to entice as many wandering Russian scientists back to Russia as possible, and to keep in Russia all those who for one reason or another—whether from a desire to see friends or family or a wish to communicate directly with scientific colleagues—decided to revisit their homeland for a while

Probably the most distinguished of this latter group was the well-known and very highly regarded physicist Peter

Kapitza, Fellow of the Royal Society of Great Britain, Director of the Royal Society's Mond Laboratory at Cambridge University, and one of the world's foremost experts on low-temperature studies Kapitza had received his training in physics at the Petrograd Institute of Technology, completing his work about the time of the 1917 Revolution He remained at this Institute (renamed Leningrad Tech) as a lecturer until 1921, when he left Russia for Cambridge, England At Cambridge he rose rapidly until he became director of the Mond Laboratory and won a respected place for himself in world science

Each year while he was in England Kapitza returned to Russia for a short visit In advance of each of these visits he obtained a letter from Russian authorities assuring that a return visa would be issued to him In 1935, however, he was persuaded not to request such a letter, on the grounds that it made him appear not to trust the Soviet government He did not request the letter, he went to Russia for his annual visit, and he never came out Although it is not known exactly what was said to Kapitza when he returned to Russia in 1935, it might well have gone something like this

"Peter Leonidovich, we are proud of you and what you have done for Russian science in the West We don't blame you for leaving in 1921, but now we would like to have you back Things have changed a lot since you left Those coarse fellows who made everything so difficult back in the early 1920s are no longer in a position of authority, and, under our great leader Stalin, the inherent value of science and scientists to Soviet society and culture is well recognized If you remain you will have your own laboratory with all the equipment and staff you need, you will be paid well, and you will have an honored place in the society of our country We want you to stay, and besides that, it will be impossible for you to leave even if you want to"

But whatever was said, and whatever motivated Kapitza, he remained in Russia Until about four years ago he applied his brilliant talent and valuable experience to the objectives of Soviet science as Director of the Institute for Physical Problems of the Academy of Sciences of the U S S R in Moscow The honors he received include two Stalin prizes, in 1941 and 1943, and the Order of Lenin in 1943

For the past four years, however, he has been under what amounts essentially to house arrest in his home outside Moscow, apparently for failure to continue to follow government instructions His only public appearances are occasional lectures in Moscow

Another result of the Soviet government's increased interest in science in the 1930s was the almost inevitable injection of the "party line" into certain areas of scientific inquiry, particularly those where some Marxist principle was at stake At the American Association for the Advancement of Science's symposium on Soviet science in 1951, published by the National Science Foundation in the book *Soviet Science*, most of the expert American observers of the Russian scientific scene who participated in the discussions agreed that unscientific political influences had penetrated many Soviet fields of scientific endeavor and badly damaged some The field most affected is probably genetics, where the quackery of the now notorious Lysenko dominates Soviet thinking with the full backing of the Soviet government Other fields in which governmental interference has hurt science and lifted quacks to positions of great prestige and influence are psychology, psychiatry, physiology, pathology, and biology The fields most free of this kind of interference are physics, chemistry, and mathematics, and these, significantly, are the lines of scientific endeavor that are most vital to a sturdy atomic energy program Although ideology is a factor in the esteem with which notable foreign physicists, chem-

ists, and mathematicians are regarded in Russia, this usually does not interfere with the utilization of their discoveries in Russian physics, chemistry, and mathematics Einstein, for example, is looked upon as being rather too much of an idealist to be rated highly as an individual in Communist eyes, but this does not prevent the Russians from accepting his theory that matter can be transformed into energy, as in an A-bomb explosion

To obtain some feeling for the quality of Russian physics, chemistry, and mathematics today, there are several places the average American layman can look There are, for example, the judgments of the American experts who know Russia best Of these, a good example is John Turkevich of the Department of Chemistry at Princeton University, who, with his wife Ludmilla, is employed by the Atomic Energy Commission's Brookhaven National Laboratory to translate Russian scientific papers for the benefit of American researchers This is what Turkevich says about Russian physics and chemistry 'It is evident to any observer that Soviet chemistry and physics is a well organized body of well trained scientists carrying out creditable work in many branches of their subject in the best tradition of the West"

Another such expert is J R Kline of the Mathematics Department of the University of Pennsylvania, a leading student of Russian mathematical activity This is what he says "I would like to describe Soviet mathematics as a most active and fruitful activity where fundamental results are being obtained and where there is no evidence of thought control" Russia has always been very strong in mathematics, and American mathematical science received a real assist from a group of Russian mathematicians who left the Soviet Union about the time of the Revolution to take teaching positions at such American institutions as Stanford, Dartmouth, Brown, and the universities of Michigan and Pennsylvania

Then consider the known accomplishments of Russian scientists in non secret areas The following random facts are both interesting and revealing

1 In 1927 the Russian physicist Skobelzyn substantially advanced nuclear research by adapting the Wilson cloud chamber to the study of cosmic rays

2 The first cyclotron in Europe was built at the Radium Institute in Moscow in 1937

3 In 1939 the two Russian physicists Flerov and Petrazhak announced their discovery of the spontaneous fission of uranium

4 In 1945 the Russian physicist Veksler developed and put forward the idea of the synchrotron about the same time that it was proposed independently by the American scientist McMillan of the Radiation Laboratory of the University of California A synchrotron is generally similar to a cyclotron, but is of advanced design

Still another good indication of the competence of Russian scientists is the information that is published in Russian scientific journals, of which there are many Scientific publications are always a good clue to the scientific health and activity of a nation, even though today, especially in Russia, a good deal of what is accomplished is never published where it would be exposed to prying Western eyes But enough is still published to tell us that scientific activity in Russia today is very vigorous

Until 1947 all scientific papers published in Russia bore titles and abstracts in English or German as well as in Russian, and two periodicals, the *Journal of Physics* and *Acta Physicochimica*, were published in all three languages In 1947, however, this practice was discontinued, and today Russian scientific publications are printed only in Russian, thus making it even more difficult for Western scientists to keep contact with the work of their Russian colleagues It is to help overcome this latest obstacle that the U S Atomic Energy Commission s Brookhaven National Labo-

ratory employs the Turkeviches to translate into English certain of the more important Russian articles, as well as the titles of all articles published in the twenty leading Russian scientific journals

I have on my desk, as I am writing this, one of the listings of Russian titles that the Turkeviches have translated I chose it at random from among many such listings I have in my bookcase It covers six issues in 1951 of *Academiya Nauk, SSSR, Doklady*, which means *Reports of the U S S R Academy of Sciences* *Doklady* is the most important scientific publication in Russia It comes out three times a month and includes articles in every field of science To have an article published in *Doklady*, a scientist must either be a member of the Academy of Sciences or his article must be sponsored by a member I note that the issue for September 1, 1951, contained thirty-six articles, and the issue for September 11, 1951, contained thirty-eight articles under such headings as mathematics, mathematical physics, chemistry, biochemistry, chemical engineering, geology, microbiology, plant physiology, and embryology

To provide an insight into the type of research areas covered by these papers, here are half a dozen of the translated titles

1 "Determination of the Ionizing Power of Particles with a Mass between the Mass of the Proton and Meson" by three scientists of the Physics Institute of the Armenian S S R Academy of Sciences

2 "Magnetic Properties of Mercury at Low Temperatures" by three scientists of the Physico-Technical Institute of the Ukrainian S S R Academy of Science

3 "Reaction of Carbon Tetrachloride with Alcohols" by two scientists of Gorki State University

4 "Generalization of Some Convergence Theorems of Power and Trigonometric Series" by a mathematician of the Kalinin State Pedagogical Institute

5 "Multiple Formation of Mesons" by two physicists of Moscow State University

6 "Angular Distribution of Energy of Secondary Radiation Given Off by Primary Cosmic Particles" by two physicists of the Physics Institute of the U S S R Academy of Science

Some of the other leading scientific publications in Russia are the *Journal of Experimental and Theoretical Physics*, *Journal of Technical Physics*, *Journal of General Chemistry*, and *Journal of Applied Chemistry* Two of the more popular journals are *Progress of the Physical Sciences* and *Progress of Chemistry*, which review the scientific journals of the Western World and report very competently to the Russians what is going on in the scientific world beyond the Iron Curtain Some of these publications are difficult to obtain in the United States, but all are shipped regularly to the Library of Congress in return for American non-secret publications sent to Russia under a formal exchange agreement

Science in Russia today is sponsored and controlled by the government, acting through the Academy of Sciences and/or the ministries of Higher Education, Health, Agriculture, various industries, and the Armed Services The Academy is divided into several sections looking after particular fields, such as chemistry, physics, and mathematics Each section in turn operates a number of institutes The section on physics and mathematics, for example, has, among others, the Institute of Physical Problems in Moscow, formerly headed by Kapitza, and the Physico-Technical Institute in Leningrad The institutes work very closely with the universities in the areas where they are located The money needed for scientific research is obtained by each institute from the Presidium of the Academy of Sciences The institute lays out its program for the year, requests the funds needed from the Presidium, and either receives or does not receive the grant At the end of

each year the institute must report to the Presidium on just what it accomplished with the money it received. If it hasn't accomplished what it said it would accomplish, it is in trouble. The total number of people associated with the Academy and its affiliates is probably more than forty thousand, including more than twelve thousand scientists and technicians.

All of this vast scientific machinery can be turned in any direction the government wishes. Much of the work in physics is undoubtedly steered in the direction of atomic energy development, just as much of the Russian work in chemistry from 1921 to 1935 was steered in the direction of synthetic rubber. Russia needed synthetic rubber, and Russia got it during that period by means of an all out applied-research program. Independently of the rest of the world, she developed a means for producing synthetic rubber from butadiene, which is derived from alcohol.

With the conclusion of World War II, the Soviets extended their practice of corraling scientists to include those they encountered in the Eastern Zone of Germany. These were immediately put to work on the projects in which the Soviet government was most interested, including atomic energy. They were taken into Russia and treated royally, although they were closely watched and controlled. At first they were permitted to leave Russia only in the company of a commissar or army officer on expeditions to East, and even West, Germany to obtain recruits for the Russian scientific programs. More recently many have been permitted to return to East Germany.

A good insight into the vigor with which the Soviet Union is pursuing atomic research and development, and the manner in which scientists are treated there, is given by a prominent German scientist who managed to escape in 1947. For obvious reasons his name cannot be given, but there is good reason to believe that he knows whereof he

speaks This is what he said in 1947 in Neustadt, Germany, after his escape

"At least 200 German scientists and technicians, including some of Germany's foremost nuclear physicists, are *working in a virtual paradise* for the Russian government on problems of nuclear physics They work in Moscow, in southern Russia, and in Siberia beyond the Urals

"German scientists get everything they want for their work and their personal needs But in reality they live in a golden cage You get paid (the equivalent of) from $14,400 to $36,000 a year They give you a big house and all the personal servants you need If you want cigarettes, you get all you can smoke If you want luxury foods, you get them But you are trapped in the golden cage

"The Russian scientists are engaged on their own projects No German scientific worker knows what the total knowledge is It is like a mosaic Somebody is collecting all the information and putting each stone into the pattern"

This German scientist, now at work in this country on projects not connected with the atomic energy program, concluded his statement with this remark "From the advanced work being done, and from what I have seen and heard, I estimate Russia will know how to make an atom bomb within three to five years' That was in 1947 Actually, the Russians exploded their first bomb in 1949

As we now know, the Russian atomic effort has been supplemented by information obtained from the West through espionage, notably from the British scientist Klaus Fuchs and the spy ring built up around him Although it is clear that Russian science could itself have developed all the knowledge it needed for an atomic weapons program, it is quite probable that the efficient spy ring around Fuchs advanced, probably by as much as a year and a half, the date by which the Russians achieved their first bomb It is now believed also that another British scientist of consid-

erable ability, Bruno Pontecorvo, disappeared behind the Iron Curtain in September 1950, where he is quite probably at work for Russian science

But the Russians need no longer rely for their scientific strength upon holdovers from the old days and imports from the West They have done much to improve and expand their educational system so that it will produce ever increasing numbers of skilled people The number of higher educational institutions in Russia, most of which nowadays are primarily concerned with producing professional personnel, has increased from about 150 in 1930 to 900 in 1952 During this same period, student enrollments have gone up from about 200,000 to about 1,400,000, including extension-course enrollees, and the annual graduating classes in the Soviet Union now total about 200,000, of which about half are scientific or technical people This last figure compares with the about 100,000 scientific or technical students who are graduated annually in the United States

About 30,000 engineers were graduated by Russian schools in 1952, and this figure may increase to about 40,000 by 1955 American production of engineers will average about 22,000 annually over the next four years, although the rate is expected to increase substantially thereafter In 1950, a more favorable year, 50,000 engineers were graduated in the United States It is difficult to give statistics regarding the Russian production of individuals corresponding to our Bachelor of Science graduates in the basic sciences, but at the level most nearly comparable to our Ph D in science it appears that Russian production is annually about equal to ours at the present time

The quality of professional training in Russia is apparently very good Admission to Russian institutions of higher learning seems to be largely on the basis of ability, and subsidies by the government make it possible for all individuals of real ability to complete their training The

published examinations that must be taken by candidates for admission to the engineering schools and universities indicate a level of secondary school training in mathematics, chemistry, and physics that is at least comparable to that expected of United States high-school graduates

In addition to the training of professional engineers, about 3,500 technical schools in Russia train specialized subprofessional technicians, and these turn out more than 250,000 trainees annually Although the United States has only about twenty such schools, this does not take into account the technical courses offered in our high schools or the vast training programs conducted in this country by industrial concerns But the Russian step-up in education at all levels is striking, and this is a fact that cannot be ignored in any evaluation of Russian scientific and technical competence

It has been said that one may characterize Russian science by paraphrasing the description of the little girl in kindergarten "When it is good, it is very, very good, but when it is bad, it is horrid" It should be of very small comfort to us that Russian science is far from horrid in those fields which relate most directly to the development of a strong atomic energy program

Production Capability

We have seen up to this point that Russia has the raw materials, including uranium, and the scientific competence necessary to a sturdy atomic energy program But what of her production and technological capabilities? Is it true, as some GI's returning home from World War II would have us believe, that the average Russian does not even have the mechanical talent to repair a broken jeep? Certainly such an impression prevails widely And is it true, as some have said, that—while Russia has able scientists and engineers at the top of her industrial structure, and an unlimited supply of labor at the bottom—she is in

very short supply of those essential intermediate people, such as skilled craftsmen, shop foremen, and divisional superintendents?

There is some truth in this generalization, but it is dangerously misleading The proof of the pudding, after all, is in the eating, and Russia during and since World War II has been mass-producing tanks, rockets, artillery, and aircraft of high quality These are facts, and one hardly needs any more of a current reminder than the behavior of the MIG-15 jet

We have consistently underrated the Russian technological and production achievement, and it is now time we stopped doing it Her performance during and since World War II is there for us to see, and it is time we started to believe what we see

If, at the end of World War II, one had plotted the relative technological achievements of the U S and the U S S R in the weapons field, he would have found that, while we were perhaps as much as two years ahead of the Russians in the development of military aircraft—giving consideration to such characteristics as speed, altitude, pay load, range, and the like—the rate of technological development generally was approximately equal In other words, if the technologists of each of the two countries had been presented with a complete set of aircraft blueprints on the same day, the race would have been a dead heat to the point of achieving the first prototype, and a dead heat again from prototype to mass production This, as much as anything else, demonstrates the high performance capability of our current rivals

For some weapons of warfare, the U S S R reached mass production two years behind the U S , for others, it was two years ahead of us The over-all rate of development, as with aircraft, was approximately equal So it was with tanks By the end of the war, Russian tanks were more heavily and powerfully armed than U S tanks, although

the American product had greater speed. Again, however, the rate of development was approximately equal.

I have heard Russia's capability in technology and weapons production deprecated by persons who assert that Russia is an imitator, and that if B-29s, to take an example, had not been forced down in Russian territory, Russia today could not be making the Russian counterpart of that airplane in quantity. I don't believe it, and here again we would do well to learn from history. Developments in the field of aircraft engines are a good illustration.

During the war the Russians compressed into two years the jump from 1,500 horsepower to 2,200 horsepower in aircraft engines, an achievement that had taken the U.S. four and one-half years. It is true that the engines developed by the Russians were modifications of German, French, and American designs, but—and this is an important "but"—the higher horsepower developments were not copies of similar developments in the Western models. They represented instead original engineering along entirely independent lines by the U.S.S.R.

World War II experience should have demonstrated that in almost every major technological effort, with the possible exception of petroleum, the Russian development rate was about equal to ours. Thus, if the American atomic energy program, for which the first production facilities were built in 1943, could test an end product in 1945, no one should have been surprised, even discounting the effects of espionage, when the Russians tested their first bomb in 1949.

Ability to Unite Other Ingredients into a Strong Program

The Russian system produces a number of advantages, as well as disadvantages, insofar as the will and ability to accomplish things is concerned. The net result, however, is that there are enough advantages to make it possible for

big things to be done in a big way—at a price in human freedom and dignity Among her at least superficial advantages is her almost unlimited supply of slave and prison labor, which, in Russian eyes, need not be fed, clothed, or treated decently and humanely With plenty of labor and with the concept that this labor is expendable, she automatically eliminates the elaborate and costly health and safety devices which a democracy must employ—and should employ

Among the disadvantages of her system is the fact that scientists and engineers do not work honestly and boldly —and therefore at their best—under the eyes of the secret police This is not the kind of atmosphere in which ideas are nurtured and brave new things are tried It is the kind of atmosphere that produces fear, and with fear comes caution and conservatism There are many examples of this

In 1942 a Russian delegation came to this country to secure information on various petroleum-refining methods After considerable study the delegation chose a method known as the Houdry process" as the one they wanted under Lend-Lease At that time the Houdry process was the only catalytic cracking process that had several years of proved refinery operation behind it Other methods had been developed, but they had not been completely perfected Some of these, however, gave evidence of soon outstripping the Houdry process in economy and production, and had, in fact, been almost universally accepted in 1942 for all future catalytic cracking units that were subsequently installed in the U S Although information on the other processes was made available to the Russians, along with the Houdry method, they were unwilling to gamble on what, from an engineering point of view, was a relatively sure thing

Russian science has also suffered over the years from purges This should be a lesson to us Whenever the gov-

ernment attempted to bend scientific findings to make them fit some political pronouncement of Marx or Lenin or Stalin, science suffered, and one finds such scientific quacks as Lysenko in positions of great influence in Russian science To date, these scientific frauds have not penetrated into an activity so vital to Soviet aggrandizement as atomic energy, but under the totalitarian Communist system, such a possibility always exists

The Russian program teaches us another lesson One always pays a heavy price for compartmentalization as an aid to security To be sure, it is safer to hold certain information to a limited few, but this frequently reduces the rate of progress We have found in the American program, for example, that when we call in all of our laboratories—not just one—to tackle a problem, our rate of progress frequently increases almost by as many times as the number of laboratories called in The Russians, under their system of compartmentalization, attempt to achieve the development of new ideas at no risk to security by the device of assigning one—and only one—of their institutes a high-priority task calling for all of the talents available in that institute I suggest, however, that on some occasions they have thereby achieved a high degree of security at a cost that must be measured in terms of a heavy loss in ideas

But on the "advantage side, the reader should bear in mind that Russia can compel any priorities that she desires, and that a vast spy network, which has been obviously successful in the past, serves her military atomic energy program He should also have in mind that Comrade Beria, who so recently headed the atomic effort, was also in charge of slave labor and the secret police These three activities are closely related in the Russian atomic energy program It might also be well if they had a relationship in the minds of the peoples of the free world, for, if Russia's atomic energy program is sufficiently successful to

conquer the world, we can expect thereafter nothing but slavery under the cold eyes of a police state—or a worse fate, that of Beria

How many bombs do the Russians have? The precise number doesn't matter They have enough, if delivered on target, to hurt this country badly A distressing thought? Yes, but a fact of life and a fact which, once understood, is the basic premise for the development in America of an intelligent national defense plan

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P S Since this chapter was written but just before it went to press the Soviets announced the explosion of a hydrogen bomb, and the Atomic Energy Commission of the United States confirmed the Russian announcement

CHAPTER *xv*

The Way Ahead

In this book we have examined the atomic energy program of the United States as it exists today. We have also glimpsed rather quickly the programs of our competitors, both friendly and hostile. But only here and there have we attempted to speculate about our future in the atomic age. Yet there is something about the atomic age—which is now just over ten years old—that intensifies man's natural curiosity about what is in store for him in the years ahead.

There have been many attempts to look into our atomic future. You have probably read novels about life on an earth all but destroyed by atomic war, seen pictures of what your community would look like if a hydrogen bomb exploded over the city hall, and heard stories of how a uranium pellet the size of an aspirin tablet might drive an ocean liner many times around the world, your car throughout its entire lifetime, or a rocket ship to the moon. You have probably listened to guesses as to when cancer will be cured, food made plentiful, free electric power produced, and new species of plants and animals created, all through atomic energy.

Some of this speculation has been based on sound scientific fact, much more, unfortunately, on romantic and unscientific fallacy. One thing, however, is clear. We know

what the atomic age has produced in its first decade Weapons of staggering power have been developed and tested and placed in our national stockpile Usable atomic power has been generated in experimental quantities Work has been undertaken on an atomic-powered submarine that will be completed next year A great, multibillion-dollar industry has been built up to manufacture the fuels and explosives of the atomic age in mass-production quantities Some diseases, notably hyperthyroidism, can already be cured or at least inhibited by radioisotopes And some farming and industrial techniques, such as fertilizer placement, radiography, and thickness measurement, have already been improved substantially through the utilization of radioactivity

Without doubt the most conspicuous progress to date has been in the field of weapons design and manufacture, but general technical advancement has also been encouraging When one considers the state of development a decade after the discovery of electricity or the invention of the internal-combustion engine, he may realize how rapid the progress in atomic energy has been

But what of the future? What really is in store for mankind in the atomic age? Probably the best answer is "Who knows?" Unfortunately, the people who are in the best position to predict have been busy doing something else during the past decade They have been busy designing and building the gargantuan facilities where fissionable materials are produced, or developing, testing, and manufacturing weapons, or pushing applied-research programs so that the results could be incorporated on an almost day-to-day basis into an enormous construction effort

The past decade has been a fluid period, an inventive period, and a period of great haste It has been a time when people have concentrated, perhaps too narrowly, upon those projects with the greatest promise of immedi-

ate practical utilization in the program to acquire ore, produce fissionable material, and manufacture weapons

I make no apology for the part I have played in maintaining this emphasis Indeed, I have considerable pride in it, for, as I have said many times before, I believe it has done much to deter another world war It has, however, left something to be desired so far as long-range planning is concerned But these days of urgent and rapid expansion are now nearly over The last major expansion program has, I hope, been undertaken Beginning now, more attention can and should be given to the job of planning for the way ahead Even out of the hectic past there have emerged a number of promising lines of endeavor that, if pursued vigorously, can begin to affect substantially our economy and our mode of life within the next decade

It is very difficult to predict with any degree of certainty just where these lines of endeavor may lead us, for our rate and direction of progress will be determined far more by unpredictable man than it will by the predictable atom It is, therefore, impossible to foresee just where we shall be in the development of atomic energy a decade from now, it is only possible to predict where we *can* be if we want badly enough to get there

Thus, by the end of the next decade it is very possible that man will be able to build atomic power plants that can compete favorably with those burning coal or oil It is quite possible that at least ten per cent, and possibly more, of all new electric generating facilities being built in the United States in the year 1963 will use nuclear fuels The percentage in some other countries, such as Belgium, where coal is expensive, might be even higher, ultimately it will certainly be higher

In ten years we should also be able to have in operation a number of reactors capable of producing power and breeding new nuclear fuel from uranium or thorium at the same time

In addition, the next ten years should see the use of atomic engines, not only in submarines, but also in large surface vessels, such as aircraft carriers of the U S Navy —*if* we want them It is also possible, although less likely, that an atomic propulsion plant will be developed that could be used economically in commercial ships We may not see all this in ten years, but it is virtually certain that we could see it within the next fifteen—again, *if* we want to

Another possibility for the next decade is an atomic-powered aircraft for the Air Force Whether this is achieved depends almost solely on how much money the government is willing to spend annually on its development I would doubt, however—no matter how much money is spent—that there will be any atomic-powered airplanes in commercial use within ten years, although it is quite possible that this will become a reality later on

One place where the atomic engine may come into its own is in the now all but forgotten field of dirigibles A dirigible could carry aloft the very heavy shielding required for an atomic engine much more easily than could an airplane The danger of fire would also be greatly reduced by the use of atomic fuels, for they will not burn in the sense that gasoline or oil will Although I would be a little surprised if any atomic-powered dirigibles were to be in commercial service by 1963, I believe an experimental model could be in the air by that time if someone were willing to pay for it I can see no reason why someday, possibly within fifteen or twenty years, such aircraft should not be available for commercial use

I believe it would even be possible within the next decade to have atomic-powered locomotives I should be surprised, however, if this were attempted by so early a date The special hazards presented by an atomic engine and the expense of developing one that might fit a loco-

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required, such as in central-station electric generating plants, in ships, and possibly in some types of large aircraft. I do not look for it to be used, at least for some time, where very small sources of power are needed, such as in house furnaces, small aircraft, or, as we have seen, in automobiles. But the use of atomic energy where large sources of power are required will certainly free our supplies of oil, coal, and gas for wider use in other places.

In fields other than power, I would expect that during the next decade radioisotopes and other sources of nuclear radiation will come into ever wider use in medicine, industry, and agriculture. More people will be trained in the techniques of using them, and the lives of more people will be helpfully affected by them. But the chances of something really spectacular occurring in this field in the next decade are little better than even. The most likely possibilities are in cancer research, where some important advances will very likely be made (although a single complete "cure" for all and any types of cancer is unlikely), in the study of photosynthesis, where there is a chance that man may uncover the secret of what makes plants grow, and in the utilization of highly radioactive materials for such purposes as the production of new chemicals or the sterilization of drugs and possibly some foods.

"But what," you may well ask, "will all this mean to me?" If you live in the industrialized East, it may mean that within ten years you will be using in your home electricity that is produced in an atomic power plant. As I have stated earlier in this book, this probably will not change your electric-light bill very much, but it may very well make your city a cleaner and more attractive place in which to live, for no smoke or fumes emerge from such a plant. Your chances of having a small reactor in your basement to provide heat and electricity directly for your home, however, are virtually nil for the next ten years and probably for many decades after that, if not forever.

motive efficiently suggest that other possible uses of atomic power will be developed first

In regard to atomic-powered automobiles, which have been discussed a good deal, I feel that they are out of the question, not only for the next decade, but probably forever The very heavy and bulky shielding required to seal in the deadly radiations emanating from atomic reactions would seem to preclude their use in so small a vehicle Also, an atomic reaction requires a minimum amount of nuclear fuel (a "critical mass") before it will operate The amount of power needed to propel an automobile is far less than the amount that can be produced by a critical mass of nuclear fuel This would therefore seem to be a highly inefficient use of so valuable a source of power There is, however, a chance that someone may someday find a way to convert the very intense radioactivity of the ashes of a nuclear fire (fission products) into heat If this were accomplished it might be possible to use small quantities of these ashes to produce heat to drive such small vehicles as automobiles I cannot see this being done within the next decade, however

Another suggested use of atomic fuel about which there has been a good deal of speculation is the propulsion of interplanetary rockets or space ships There is one major drawback here An aircraft or guided missile using an atomic reactor for power could propel itself through the earth's atmosphere by taking air in through the front of the craft, heating and thereby expanding it, and then ejecting it out the rear, in the manner of a jet But in space there is no atmosphere An atomic space ship would therefore have to carry along some substance which could be heated and ejected in order to propel itself The problems of weight and bulk that face the designers of space craft are therefore not automatically solved by atomic energy

In general, in the field of power I look for atomic energy to be utilized gradually where large sources of power are

investment will be created, new regions of the earth opened up and developed, new products produced and marketed, and new life-saving techniques introduced into the world of medicine The atomic age can be a hopeful, prosperous, and happy age Or, as has been said many times in the past, it can be the age in which man finally succeeds in destroying himself

The other side of the atom—the weapons side—is very real There is no point in trying to pretend that it doesn't exist or that it is not a dangerous threat to civilization The simple truth is that the weapons stockpiles that are being accumulated in various countries of the world today are rapidly approaching the point where mankind will have the capability to destroy everything on earth The central problem of the atomic age, obviously, is to avoid such a holocaust This is not a scientific or technical problem, however, it is a political one, and if it is to be solved it must be solved by diplomatic and political means

Wars and threats of wars have been a part of man's life all through history Although many have tried, no one has yet solved the problem of war But now the atomic age has introduced a new factor that must be taken into the calculations Whereas before the problem was simply one of war or peace, it is now one of oblivion or peace With a question like this, it is hard to imagine any answer except peace Yet man, even in the atomic age, has not chosen peace He also has not chosen oblivion, and he seems to think he can go on forever without deciding upon one or the other Maybe he can, but the risks are enormous

In this situation, there is one thing that clearly suggests itself as a desirable and perhaps necessary step This is to undertake an intensive educational campaign to show the people of this country, of the Soviet Union, and of the entire world what atomic and hydrogen weapons can really do As part of this step, I think we must give the public some idea of the magnitude of our stockpile and its tre-

If you live in an undeveloped part of the country, such as sections of the Rocky Mountain region, your chances of being more directly affected by the coming of atomic power are somewhat greater. It may be, for example, that you will have large quantities of electricity available where before you had none or very little. It may mean some mineral deposits can be worked that are now undeveloped for lack of power, or that some areas can be irrigated that are now barren because there is no power, or not enough power, to pump in fresh water. The presence of ample power may also mean that new industries will move into your section in order to be closer to the raw materials produced there. I doubt, however, that more than the very beginnings of these changes will be noticeable in ten years.

No matter where you live, there is an excellent chance that within the next decade either your life or the life of someone you know will be saved or prolonged or made more comfortable by the use of radioisotopes. There is also an excellent chance that you will have occasion to buy some industrial product, such as a tire or an engine lubricant or a detergent, that has either been developed or improved through work with radioisotopes. If you are a farmer, there is every likelihood that you will use some information, given you by your county agent or local agricultural experiment station, that has been derived from experimentation with radioisotopes. Work with these immensely valuable materials will affect you increasingly in scores of different ways as time passes.

These, however, are only the things that we know about and can predict with some degree of certainty on the basis of the knowledge we already have. I believe, and I feel that nearly everyone connected with the atomic energy program believes, that there is more in the atom than this. But even if there is not, it is still possible for us to visualize an era in which new opportunities for employment and

hold dear to Russian Communism, or inviting Soviet aggression through unilateral disarmament

Our national policy today is to deter aggression while we continue to look for the avenue that might lead to a real peace, and while we build up the economic and defensive strength of our friends and allies in the free world The atom is vital to all of these goals It is the bulwark of our plans for the defense of ourselves and our allies, it is the "big stick" that we hope may ultimately encourage the nations of the world to establish a secure peace, and it is an important means by which we may help to improve the economic health of the free world

The importance of atomic energy to the future economic health of the free world must not be underrated If the present uneasy truce between the East and the West continues indefinitely, it will probably be because the Soviet Union is betting that the industrial economy of the Western nations will ultimately collapse through overproduction, unemployment, and depression It is axiomatic that we cannot afford to let this happen Atomic energy can help to keep it from happening One of the secrets of the success of Western democracy is that it contains within itself the means by which its economy can be constantly rejuvenated By providing for free enterprise and the stimulation of competition, the West has produced one new industry after another that has kept its economy from becoming stagnant Examples are the automobile industry, the aircraft industry, and, more recently, the electronics and synthetic-fibre industries

Now it is the atomic energy industry Atomic energy can help the economy of the free world in at least three ways It can provide a new, inexpensive source of power that can help reduce industrial production costs in many parts of Europe and elsewhere, it can create new markets for the industrial production of Europe and America by helping to open up and develop the backward areas of

mendous destructive potential In flirting with world war in the atomic age, man is not playing with fire, he is playing with the means by which mortal life on earth can be ended

The decision to undertake a real educational campaign of this nature is not something that can be done alone by one agency of government, such as the Atomic Energy Commission Such a program would have to be undertaken by the whole government, and the whole government, including both the Executive Branch and the Congress, would have to agree that it was a worth-while and necessary thing to do But if it is undertaken, it will at least provide the peoples of the world, including the diplomats, with an accurate idea of the nature of the choice that faces them If they have been unable to make the right choice in partial ignorance, perhaps they will be encouraged to make it if they are given a true picture of the tremendously destructive potential of the world's stockpile of atomic weapons

Continued procrastination by the nations of the world in the area of peace and war need not necessarily be fatal, of course If no permanent and secure peace is achieved, it is possible for the world to continue to exist in a state of uneasy truce The risks of such a situation, however, are naturally great Unless a real and secure peace can be achieved, we have no choice but to remain strong in the hope that the hand of a potential aggressor will be stayed by the threat of absolute retaliation before he makes the irrevocable move Here again the atom plays a leading role If world wars cannot be eliminated in the atomic age through agreement, perhaps they can be eliminated through fear of retaliation This has been the case during the past eight years, and it may be possible to extend this situation indefinitely Although it is a very weak reed upon which to lean, it is certainly better, in my view, than surrendering our freedom, our dignity, and all we

ize people in all walks of life with atomic energy and its implications This can be done partly by the government, but it also requires the co-operation of organizations outside of government

7 Constant review of our security and secrecy restrictions with a view to making public such information as would clearly help the attainment of world peace, the development of a good civil defense plan, co-operation between the free nations of the world, and the attainment of economically feasible atomic power without hopelessly damaging our national defense position

8 Strong civilian control and responsibility in keeping with the spirit of the Atomic Energy Act of 1946, but always with the closest possible liaison between the Atomic Energy Commission and the armed services

The Atomic Energy Commission can do much to carry such a program forward It can, for example, preserve a strong *esprit de corps* among the many elements of the atomic energy program scientific, technical, industrial, and educational It can keep good relations with the Congress, with the other agencies of the government, and with the general public, thus preventing squabbles and arguments from slowing up essential work It can keep its nose to the grindstone, turning out rapidly the fissionable materials and weapons necessary to a strong defense program, and it can do this efficiently, at low unit cost, by businesslike methods and by abiding by the concepts of fairness and impartiality which must accompany the handling of public funds It can make its case and its program known and substantially understood And it can, by leadership and example, foster basic research, encourage industrial participation, and keep the program not only effective but farsighted

But the Commission cannot do it all In particular, it has no direct responsibility in the effort—of overriding importance—to secure world peace This is the job of the diplo-

the world, and, while it is building, it can create new demands for technical equipment and materials that can inject a fresh life into the industrial economy of the West There is, therefore, a national and international security reason why we should pursue as vigorously as we can the development of the peaceful applications of atomic energy

If we are to work toward these goals, however, we must have a strong and clearly defined program for the immediate future My program would consist of the following basic elements

1 The vigorous prosecution of a never-ceasing effort to bring a real and stable peace to the world

2 In the absence of a stable peace, no loss of time or momentum in the huge construction program now under way and, above all, no cutback in this program The facilities now being built should represent the last substantial plant and equipment outlay for the production of fissionable material, but they should be built as fast as possible and operated at full capacity until we have all of the weapons we will need to destroy completely the power of any aggressor to make war

3 A vigorous basic and applied research program designed to keep in front of the whole world all phases of the field of atomic energy

4 An atomic energy law flexible enough to permit the Atomic Energy Commission and industry to develop economically feasible power either independently or jointly

5 A law flexible enough to give the Commission power to trade information on atomic power with countries supplying ore to the United States, as well as, at the appropriate time, with potential suppliers of ore and to countries friendly with the United States who have a special interest in power or other peaceful products of atomic energy

6 An intensive public-information program to familiar-

of every citizen in policy-making has always been important in our democracy, in a world that also contains the unleashed atom it is vital

Mankind has recently entered a room, the door to which is labeled the atomic age We are in that room, and we have found that it is so large and so dimly lighted that we cannot yet begin to perceive all that is in it But we have crossed the threshold, and we cannot turn back All we can do is go forward as boldly, and yet as wisely, as we can One of the great responsibilities that we in America assumed when we brought the atomic bomb into the world was to lead the way into the atomic age To do it well, our statesmen will need the understanding, the guidance, and the help of every citizen

mat and the statesman and the policy maker To a greater degree than you realize, it is your, the reader's, responsibility, because what you think and say and do is what determines the actions of the statesmen and the diplomats In the last analysis, you and others like you are the policy makers

Do you think our government is doing all it can to obtain peace in the atomic age? Do you think we should say more about the number and kinds of bombs we have and what they will do if it will help to bring peace? Do you think we should take the cloak of secrecy off the information about atomic power in the hope that we can stimulate progress? Do you think we should give some of our atomic energy information to friendly countries to help strengthen the economy of the free world? In the absence of a real peace, do you think we should drive our atomic weapons program forward until we have all the weapons we will ever need to destroy anyone who may undertake aggression against our friends or ourselves? Do you think the government's monopoly in atomic energy should be relaxed to permit competitive industry to join the drive for realization of the peaceful promise of the atom?

Do you feel strongly enough about all or any of these things to make some sacrifices to help your point of view win out—sacrifices measured in terms of paying taxes, of running for office, of leading study and discussion groups, of working with civic organizations, of writing letters to your Congressman, or perhaps just of educating yourself and participating intelligently in conversations with your family, neighbors, and friends?

If you are not interested enough to do any of these things, you are not earning your right to live in and enjoy the benefits that can be yours in the atomic age Furthermore, you will be letting the world drift toward atomic war and oblivion by default Something more than indifference or revulsion is called for here The participation

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A NOTE ON THE TYPE

THE TEXT of this book is set in Caledonia, *a Linotype face designed by W. A. Dwiggins. It belongs to the family of printing types called "modern face" by printers—a term used to mark the change in style of type-letters that occurred about 1800. Caledonia borders on the general design of Scotch Modern, but is more freely drawn than that letter.*

The book was composed, printed, and bound by The Plimpton Press, Norwood, Massachusetts. Binding design by W. A. Dwiggins.